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OPTICAL HEAD DEVICE, INCLINATION DETECTION APPARATUS USING THE SAME, AND OPTICAL INFORMATION PROCESSING APPARATUS USING THE SAME
by

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CERTIFICATION UNDER 37 CFR 1.10

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This application is a division application of copending application serial number 09/288,304, filed on April 8, 1999, which was a continuation-in-part application of copending application serial number 08/877,363, filed on June 17, 1997.

5   BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

The present invention relates to an optical head device for recording information to, or reproducing or
10   erasing information from, an information memory medium, for example, an optical disk or optical card. The present invention also relates to an optical information processing apparatus, and an inclination angle detection apparatus for detecting an angle made by a beam collected by a light
15   collection system in an optical information processing apparatus and an information memory medium.

2. DESCRIPTION OF THE RELATED ART:

Optical memory technologies which use optical disks
20   or optical cards as high density, large capacity memory media are used in progressively wider fields, for example, in digital audio disks, video disks, document file disks and data files.   By such optical memory technologies, information is recorded to, or reproduced from, an optical
25   disk with sufficiently high precision and satisfactory reliability through a light beam which is focused to have a microscopic diameter. The performance of a recording and reproduction apparatus using the optical memory technologies significantly relies on the optical system.
30

Exemplary basic functions of the optical head device, which is a main part of the optical system, are rough classified into:

(1) light collection in order to form a smallest possible light spot only limited by the diffraction;

5   (2) focusing and tracking control of the optical system, and reproduction of information signals; and

(3) erasing and writing of information signals by collected light.

10

These functions are realized by a combination of various optical systems and a light detector of a photoelectric conversion system.

15   As a first conventional example comparative to the present invention, a conventional optical head device will be described with reference to Figure **42**. Figure **42** is a schematic view of an optical system of the conventional optical head device. In the optical head device shown in

20   Figure **42**, focusing is performed by the non-point aberration method and tracking is performed by the push-pull method and the phase contrasting method.

The optical head device shown in Figure **42** operates

25   in the following manner.

Light emitted by a semiconductor laser **101** as a light source is reflected by a plane-parallel beam splitter **102** and collimated by a collimator lens **103**, which is included

30   in a light collection system. The light is then collected by an objective lens **104** which is also included in the light collection system, and collected on an information layer **108** of an optical disk **105**, which is an information memory

medium. An actuator **107** moves the objective lens **104** and a holding device **106** in accordance with fluctuations or decentration of the optical disk **105**.

5   The light is then diffracted and reflected by the information layer **108** of the optical disk **105** to be reflected light **108a**. The reflected light **108a** is converged by the collimator lens **103**. The reflected light **108a** is then provided with an non-point aberration when passing through

10   the plane-parallel beam splitter **102**. The light provided with the non-point aberration is received by a light detector **150**. The above-described elements in the optical system shown in Figure **42** are arranged so that, when a focal point F0 of the light from the objective lens **104** is on the

15   information layer **108**, a light detecting surface of the light detector **150** is in the least circle of confusion of the converged light provided with the non-point aberration.

       Figure **43A** shows a pattern of a light detection area

20   of the light detector **150** and the shape of a cross section of the reflected light **108a** detected by the light detector **150**. The light detector **150** includes four light detection areas **251** through **254**. Signals obtained in accordance with the amount of light received by the light detection areas

25   **251** through **254** are referred to herein as s1 through s4. Although an operation circuit for generating a tracking error signal is not shown, a tracking error signal TE1 is generated according to expression (1).

30     $$TE1=(s1+s4)-(s2+s3) \ldots (1)$$

       By the phase contrasting method, a tracking error signal TE2 is obtained by comparing the phase of a sum signal

of s1 and s3 and the phase of a sum signal of s2 and s4.

A focusing error FE signal by the non-point aberration method is generated according to expression (2).

$$FE=(s1+s3)-(s2+s4) \ldots (2)$$

When the information layer 108 of the optical disk 105 is distanced from the objective lens 104 so as to be beyond the focal point F0 of the light from the objective lens 104, the cross section of the reflected light 108a detected by the light detector 150 is as shown in Figure 43B. When the information layer 108 of the optical disk 105 approaches the objective lens 104 so as to be between the objective lens 104 and the focal point F0 of the light from the objective lens 104, the cross section of the reflected light 108a detected b the light detector 150 is as shown in Figure 43C.

An RF signal, which is an information reproduction signal, is a sum of the signals s1 through s4 obtained from all the light detection areas and thus is generated according to expression (3).

$$RF=s1+s2+s3+s4 \ldots (3)$$

The conventional optical head device described above have the following problems.

(1) The tracking error signal is generated by a differential signal which indicates the difference between the signals respectively obtained from the two light detection areas defined by simply equally dividing the light

detection surface (aperture) of the light detector **150** into two by a central line of the aperture. In such a structure, the light is incident off the track or tracking is not stably controlled when an aberration occurs due to an inclination

5   of the objective lens **104** and/or the optical disk **105** (tilt), or when the objective lens moves in a direction perpendicular to the tracks with respect to the optical axis in accordance with the decentration of the optical disk **105**.

10   (2) When the focal point of the light from the objective lens **104** scans the position off the track in which the information to be reproduced is stored, if a reproduction signal is generated by a signal indicating the difference between the signals respectively obtained from the two light

15   detection areas defined by simply equally dividing the aperture of the light detector **150** into two by a central line of the aperture, a sufficient margin with respect to the disturbance cannot be secured.

20   Regarding an inclination angle detection apparatus for detecting an inclination of a beam collected by a light collection system in an optical information processing apparatus with respect to the information memory device, various structures have been proposed in order to accurately

25   read information from, and write information to, the information memory device.

As a second conventional example comparative to the present invention, a conventional inclination detection

30   apparatus will be described with reference to Figure **44**. Figure **44** is a schematic view of an inclination detection apparatus. The inclination detection apparatus shown in Figure **44** operates in the following manner.

A linearly polarized scattering beam **70** emitted from a semiconductor laser **101** as a light source is collimated by a collimator lens **103** and then is incident on a polarizing beam splitter **130**. Next, the beam **70** is transmitted through the polarizing beam splitter **130** and then through a 1/4-wave plate **122** to be converted into a circularly polarized beam. The circularly polarized beam is collected on an optical disk **105** as an information memory medium by an objective lens **104**.

Figure **45** shows a structure of the optical disk **105**. In Figure **45**, Gn-1, Gn, Gn+1, ... each represent a guide groove. Information is stored in the guide grooves as a mark or a space. Accordingly, tracks Tn-1, Tn, Tn+1, ... for storing information correspond to the guide grooves Gn-1, Gn, Gn+1, ... Also in Figure **45**, Gp represents a space between two adjacent guiding grooves (i.e., cycle of the grooves), and tp represents a space between two adjacent tracks (i.e., cycle of the tracks). The values of Gp and tp are equal to each other.

The beam **70** which is reflected and diffracted by the optical disk **105** is again transmitted through the objective lens **104** and then through the 1/4-wave plate **122** to be converted into a linearly polarized beam which runs in a direction perpendicular to the direction of the light emitted from the semiconductor laser **101**. The beam **70** is then entirely reflected by the polarizing beam splitter **130** and converted into a converged beam (still indicated by reference numeral **70**) by a detection lens **133**. The converged beam **70** is transmitted to the planar polarizing plate **134** and received by a light detector **158**. The beam **70** is provided

with a non-point aberration for focusing error detection when passing through the planar polarizing plate **14**. The beam **70** received by the light detector **158** is converted into an electric signal in accordance with the light amount thereof.

In this specification, in the case where the optical disk is a ROM disk, a mark indicates a pit, and a space indicates a plane part. In the case where the optical disk indicates a phase-change memory medium, a mark indicates an amorphous portion and a space indicates a crystal portion, or a mark indicates a crystal portion and a space indicates an amorphous portion. In the case where the optical disk is a magnetic memory medium, a mark indicates an upward magnetization and a space indicates a downward magnetization, or a mark indicates a downward magnetization and a space indicates an upward magnetization. Alternatively, in the case where the optical disk is a magnetic memory medium, a mark may indicate a rightward magnetization and a space may indicate a leftward magnetization, or a mark may indicate a leftward magnetization and a space may indicate a rightward magnetization. In the case where the optical disk is a write-once disk such as a CD-R, a mark indicates a dye burned area and a space indicates a non dye burned area.

The focusing error signal and the tracking error signal are each added to the actuator **107**. The position of the objective lens **104** is adjusted so that the beam **70** emitted by the light source **101** is focused at a desired position on the optical disk **105**. The methods for generating a focusing error signal and a tracking error signal are well known and thus will not be described here.

Figure **46** shows a signal processing section **703** including the light detector **158**. The electric signal from the light detector **158** is input to the signal processing section **703**. As shown in Figure **46**, the light detector **158** includes four light detection sections **158A**, **158B**, **158C** and **158D**. The signals from the light detection sections **158A** through **158D** are respectively current/voltage converted by current/voltage converters **855** through **858**. The signals from the current/voltage converters **855** through **858** are sent to an operation section **871** for a differential operation. The signal from the operation section **871** is output from a terminal **814**. The signal from the terminal **814** is an inclination detection signal.

In the case where an inclination is detected by the above-described conventional inclination detection apparatus utilizing that eclipse of the beam **70** reflected by the optical disk **105** occurs by the aperture diaphragm of the objective lens **104**, the detection sensitivity reduces as the numerical aperture of the objective lens **104** increases. Recently, a structure has been proposed in which the numerical aperture of the light collection system is 0.6 and the thickness of the information memory medium is 0.6 mm in order to increase the information which can be stored in one information memory medium. In such a structure, a mere about 0.5 degree change in the angle made by the beam collected by the objective lens and the information memory medium significantly changes the jitter characteristics of the information read from the information memory medium. In the case where an inclination servo for compensating for the change in the angle made by the beam collected by the objective lens is introduced, the inclination detection

apparatus needs to detect the inclination with an error of 0.5 degrees or less. However, in the conventional inclination detection apparatus, when the numerical aperture of the objective lens is 0.6, even if the inclination is actually, for example, 0.5 degrees, the inclination detection signal changes only by about 2%. Thus, it is difficult to precisely detect the inclination of 0.5 degrees or less.

As a third example comparative to the present invention, another conventional optical head device will be described with reference to Figure 47.

A linearly polarized scattering beam 70 emitted by a semiconductor laser 101 as a light source is collimated by a collimator lens 103 and then is incident on a polarizing beam splitter 130. The beam 70 is transmitted through the polarizing beam splitter 130 and then through a 1/4-wave plate 122 to be converted into a circularly polarized beam. The circularly polarized beam is collected on an optical disk 105 by an objective lens 104. The beam 70 reflected and diffracted by the optical disk 105 is again transmitted through the objective lens 104 and then through the 1/4-wave plate 122 to be converted into a linearly polarized beam which travels in a direction perpendicular to the direction of the light emitted from the semiconductor laser 101. The beam 70 is then entirely reflected by the polarizing beam splitter 130 and converted into a converged beam (still indicated by reference numeral 70) by a detection lens 133. The converged beam 70 is transmitted to the planar polarizing plate 134 and received by a light detector 158. The beam 70 is provided with a non-point aberration for focusing error detection when passing through the planar polarizing plate

134. The beam **70** received by the light detector **158** is converted into an electric signal in accordance with the light amount thereof.

5   Figure **48** shows a signal processing section **705** including the light detector **158**. The electric signal from the light detector **158** is input to the signal processing section **705**. As shown in Figure **48**, the light detector **158** includes four light detection sections **158A**, **158B**, **158C** and
10   **158D**. The signals from the light detection sections **158A** through **158D** are respectively current/voltage converted by current/voltage converters **851** through **854**. The signals from the current/voltage converters **851** and **854** are added together by an addition section **891**, the signals from the
15   current/voltage converters **852** and **853** are added together by an addition section **892**, the signals from the current/voltage converters **851** and **853** are added together by an addition section **893**, and the signals from the current/voltage converters **852** and **854** are added together by
20   an addition section **894**. The signals from the adding sections **891** and **892** are sent to an operation section **871** for a differential operation, and the signals from the adding sections **893** and **894** are sent to an operation section **872** for a differential operation. The signal from the operation
25   section **871** is output from a terminal **811**, and the signal from the operation section **872** is output from a terminal **812**. The signal output from the terminal **811** is a tracking error signal, and the signal output from the terminal **812** is a focusing error signal. The focusing error signal is
30   generated by a well known method referred to as the "non-point aberration method", and the tracking error signal is generated by a well known method referred to as the "push-pull" method. The focusing error signal and the

tracking error signal are respectively added to an actuator **107** for focusing control and another actuator **107** for tracking control. The position of the objective lens **104** is adjusted so that the beam **70** from the semiconductor laser **101** is focused at a desirable position on the optical disk **105**.

Figure **49** shows a structure of the optical disk **105** (Figure **47**). In Figure **49**, Gn-1, Gn, Gn+1, ... each represent a guide groove for allowing tracking error signal detection. Information is stored in and between the guide grooves as a mark or a space, where a space between two adjacent guiding grooves is Gp and a space between two adjacent tracks is tp, Gp=2·tp.

In the optical head device described as the third example, the following conditions, for example, are adopted in order to store a great amount of information in the optical disk **105**. The wavelength λ of the beam **70** from the semiconductor laser **101** as the light source is 650 nm, the numerical aperture NA of the objective lens **104** is 0.6, the thickness t of the optical disk **105** is 0.6 mm, the distance Gp between centers of two adjacent guiding grooves is 1.48 μm, and the distance tp between centers of two adjacent tracks is 0.74 μm. When the angle made by the beam **70** collected by the objective lens **104** and the optical disk **105** is a proper angle, the tracking error signal zero-crosses when the center of the guiding groove is irradiated by the beam **70** collected by the objective lens **104**. However, when the angle made by the beam **70** collected by the objective lens **104** and the optical disk **105** is not a proper angle, the tracking error signal does not zero-cross when the center of the guiding groove is irradiated by the beam **70** collected by

the objective lens **104**. At this point, the tracking error signal is hardly offset but is phase-shifted. Such a phase shift can be a cause of an off-track. For example, when the phase shift is about 0.5 degrees, a 0.1 μm off-track is
5   caused. When the off-track is caused, the information stored in the optical disk cannot be accurately read or erased.

<div style="text-align:center">SUMMARY OF THE INVENTION</div>

10
According to one aspect of the invention an optical head device includes a light source for emitting light; a collection optical system for collecting the light emitted by the light source to an information memory medium including
15   at least one of a track having a mark or a space selectively arranged, and a track having a prescribed groove; a light detector having a plurality of detection areas for receiving the light reflected by the information memory medium and outputting a signal in accordance with a light amount of
20   the light received; a division element for dividing the light reflected by the information memory medium and allowing the light to be received by the light detector; a switch element for receiving a first signal and a second signal, which are respectively obtained in accordance with the reflected light
25   incident on a first prescribed area and a second prescribed area of the division element and outputting either one of the first signal or the second signal, the first and second prescribed areas being obtained by dividing the division element along at least one division line; and an information
30   reproduction signal generator for receiving the signal output by the switch element and generating information recorded on the track. The switch element outputs either one of the first signal and the second signal in accordance

with a distance and a positional relationship between a light collection point of the light output from the collection light system and the track.

5   In one embodiment of the invention, the division element is divided into at least three areas by at least two division lines which are substantially parallel to a tangent of the track. Where either two of the at least two division lines are defined as a first division line and a
10   second line, an area sandwiched between the first division line and the second division line is defined as area B, an area outside the first division line is defined as area A, and an area outside the second division is defined as area C; the first prescribed area includes the area A and the
15   area B, and the second prescribed area includes the area B and the area C.

     In one embodiment of the invention, the division element has a transverse division line which is
20   substantially vertical to a tangent of the track of the information memory medium and a longitudinal division line which is substantially parallel to the tangent of the track, and each of the first prescribed area and the second prescribed area is one of at least three areas obtained by
25   dividing the division element by the transverse division line and the longitudinal division line, the first prescribed area and the second prescribed area being opposite to each other with respect to the longitudinal division line.

30

     In one embodiment of the invention, the division element is divided into at least four areas by the transverse division line which is substantially vertical to the tangent

of the track of the information memory medium and at least two longitudinal division lines which are substantially parallel to the tangent of the track. Where either two of the at least two longitudinal division lines are defined

5   as a first longitudinal division line and a second longitudinal division line, an area surrounded by the first longitudinal division line, the second longitudinal division lines and the transverse division line is defined as area B, an area surrounded by the first longitudinal

10   division line and the transverse division line and bordering on the area B is defined as area A, an area surrounded by the second longitudinal division line and the transverse division line and bordering on the area B is defined as area C; the first prescribed area includes the area A and the

15   area B, and the second prescribed area includes the area B and the area C.

       According to another aspect of the invention, an optical head device includes a light source for emitting

20   light; a collection optical system for collecting the light emitted by the light source to an information memory medium including at least one of a track having a mark or a space selectively arranged, and a track having a prescribed groove; a light detector having a plurality of detection

25   areas for receiving the light reflected by the information memory medium and outputting a signal in accordance with a light amount of the light received; a division element for dividing the light reflected by the information memory medium and allowing the light to be received by the light

30   detector; and an information reproduction signal generator for reproducing information recorded on the track based on a differential signal obtained in accordance with the reflected light which is incident on a first prescribed area

and the reflected light which is incident on a second
prescribed area, the first and second prescribed areas being
obtained by dividing the division element along at least
one division line. A region included in at least one of the
5   first prescribed area and the second prescribed area is
enlarged or reduced in accordance with a distance and a
positional relationship between a light collection point
of the light output from the collection light system and
the track.
10

According to still another aspect of the invention,
an optical head device includes a light source for emitting
light; a collection optical system for collecting the light
emitted by the light source to an information memory medium
15   having a first track having at least one of a mark and a
space selectively arranged or having a prescribed groove,
a second track substantially parallel to the first track
and away from the first track by a prescribed distance, and
a third track substantially parallel to the first track and
20   away from the first track by a prescribed distance opposite
from the second track; a light detector having a plurality
of detection areas for receiving the light reflected by the
information memory medium and outputting a signal in
accordance with a light amount of the light received; a
25   division element for dividing the light reflected by the
information memory medium and allowing the light to be
received by the light detector; and an information
reproduction signal generator for reproducing information
recorded on the track based on a differential signal obtained
30   in accordance with the reflected light which is incident
on a first prescribed area and the reflected light which
is incident on a second prescribed area, the first and second
prescribed areas being obtained by dividing the division

element along at least one division line. A cross-section of the reflected light on the division element is a substantial circle having a radius R. The division element is divided into three areas by a first division line substantially parallel to a tangent of the tracks and away from a center of the substantial circle by a prescribed distance d and a second division line substantially parallel to the tangent of the tracks and away from the center of the substantial circle by the prescribed distance d opposite from the first division line. Where an area outside the first division line is defined as area A, an area sandwiched between the first division line and the second division line is defined as area B, and an area outside the second division line is area C; when a light collection point from the collection optical system is at a position on an extended line from the first track and away from the second track by a prescribed distance, information recorded on the second track is obtained by the information reproduction signal generator with the area A being the first prescribed area and the area B and the area C being collectively the second prescribed area; and when a light collection point from the collection optical system is at a position on an extended line from the first track and away from the third track by a prescribed distance, information recorded on the third track is obtained by the information reproduction signal generator with the area A and the area B being collectively the first prescribed area and the area C being the second prescribed area.

In one embodiment of the invention, the prescribed distance d from the center of the substantial circle on the division element to each of the division lines is $0.1 \times R$ or more and to $0.3 \times R$ or less.

In one embodiment of the invention, the division element is divided into at least four areas by a transverse division line which is substantially vertical to the tangent of the track of the information memory medium, a first longitudinal division line which is substantially parallel to the tangent of the track and away from the center of the substantial circle by the prescribed distance d, and a second longitudinal division line which is substantially parallel to the tangent of the track and away from the center of the substantial circle by the prescribed distance d opposite from the first longitudinal division line. An area surrounded by the first longitudinal division line and the transverse division line is defined as area A, an area surrounded by the first longitudinal division line, the second longitudinal division line and the transverse division line is defined as area B, and an area surrounded by the second longitudinal division line and the transverse division line is defined as area C, the prescribed distance d being shorter than the radius R.

According to still another aspect of the invention, an optical head device includes a light source for emitting light; a collection optical system for collecting the light emitted by the light source to an information memory medium having a first track having at least one of a mark and a space selectively arranged or having a prescribed groove, a second track substantially parallel to the first track and away from the first track by a prescribed distance, and a third track substantially parallel to the first track and away from the first track by a prescribed distance opposite from the second track; a light detector having a plurality of detection areas for receiving the light reflected by the

information memory medium and outputting a signal in accordance with a light amount of the light received; a division element for dividing the light reflected by the information memory medium and allowing the light to be

5 received by the light detector; and an information reproduction signal generator for reproducing information recorded on the track based on a differential signal obtained in accordance with the reflected light which is incident on a first prescribed area and the reflected light which

10 is incident on a second prescribed area, the first and second prescribed areas being obtained by dividing the division element along at least one division line. A cross-section of the reflected light on the division element is a substantial circle having a radius R. The division element

15 is divided into four areas by a first division line substantially parallel to a tangent of the tracks of the information memory medium and away from a center of the substantial circle by a prescribed distance d, a second division line substantially parallel to the tangent of the

20 tracks and away from the center of the substantial circle by the prescribed distance d opposite from the first division line, and a third division line passing through the center of the substantial circle. Where an area outside the first division line is defined as area A, an area sandwiched

25 between the first division line and the third division line is defined as area B, an area sandwiched between the second division line and the third division line is defined as area C, and an area outside the second division line is area D; when a light collection point from the collection optical

30 system is at a position on an extended line from the first track and away from the second track by a prescribed distance, information recorded on the second track is obtained by the information reproduction signal generator with the area A

being the first prescribed area and the area C and the area
D being collectively the second prescribed area; and when
a light collection point from the collection optical system
is at a position on an extended line from the first track
5 and away from the third track by a prescribed distance,
information recorded on the third track is obtained by the
information reproduction signal generator with the area A
and the area B being collectively the first prescribed area
and the area D being the second prescribed area, the
10 prescribed distance d being shorter than the radius R.

In one embodiment of the invention, the division
element is divided into at least five areas by a transverse
division line which is substantially vertical to the tangent
15 of the track of the information memory medium, a first
longitudinal division line which is substantially parallel
to the tangent of the track and away from the center of the
substantial circle by the prescribed distance d, a second
longitudinal division line which is substantially parallel
20 to the tangent of the track and away from the center of the
substantial circle by the prescribed distance d opposite
from the first longitudinal division line, and a third
division line passing through the center of the substantial
circle; an area surrounded by the first longitudinal
25 division line and the transverse division line is defined
as area A, an area surrounded by the first longitudinal
division line, the third longitudinal division line and the
transverse division line is defined as area B, an area
surrounded by the second longitudinal division line, the
30 third longitudinal division line and the transverse division
line is defined as area C, and an area surrounded by the
second longitudinal division line and the transverse
division line is defined as area D.

According to still another aspect of the invention,
an optical head device includes a light source for emitting
light; a collection optical system for collecting the light
5   emitted by the light source to an information memory medium
including at least one of a track having a mark or a space
selectively arranged, and a track having a prescribed
groove; a light detector having a plurality of detection
areas for receiving the light reflected by the information
10   memory medium and outputting a signal in accordance with
a light amount of the light received; a division element
for dividing the light reflected by the information memory
medium and allowing the light to be received by the light
detector; and an information reproduction signal generator
15   for reproducing information recorded on the track based on
a differential signal obtained in accordance with the
reflected light which is incident on a first prescribed area
and the reflected light which is incident on a second
prescribed area, the first and second prescribed areas being
20   obtained by dividing the division element along at least
one division line. A cross-section of the reflected light
on the division element is a substantial circle having a
radius R. The division element is divided into at least
three areas by at least two division lines substantially
25   parallel to the tangent of the track of the information
memory medium and away from a center of the substantial
circle by a prescribed distance d. Where a light collection
point from the collection optical system is at a position
away from the track by a prescribed distance, with an area
30   among the three areas which excludes the center of the
substantial circle being a first prescribed area, and
another area among the three areas which excludes the center
of the substantial circle being a second prescribed area,

information recorded on the track is obtained by the information reproduction signal generator, the prescribed distance d being shorter than the radius R.

5   In one embodiment of the invention, the division element is divided into at least four areas by a transverse division line which is substantially vertical to the tangent of the track of the information memory medium, a first longitudinal division line which is substantially parallel
10   to the tangent of the track and away from the center of the substantial circle by the prescribed distance d, and a second longitudinal division line which is substantially parallel to the tangent of the track and away from the center of the substantial circle by the prescribed distance d opposite
15   from the first longitudinal division line; an area surrounded by the first longitudinal division line and the transverse division line is defined as the first prescribed area, an area surrounded by the second longitudinal division line and the transverse division line is defined as the
20   second prescribed area.

According to still another aspect of the invention, an optical head device includes a light source for emitting light; a collection optical system for collecting the light
25   emitted by the light source to an information memory medium including at least one of a track having a mark or a space selectively arranged, and a track having a prescribed groove; a light detector having a plurality of detection areas for receiving the light reflected by the information
30   memory medium and outputting a signal in accordance with a light amount of the light received; a division element for dividing the light reflected by the information memory medium and allowing the light to be received by the light

detector; and an information reproduction signal generator for reproducing information recorded on the track based on a differential signal obtained in accordance with the reflected light which is incident on a first prescribed area
5   and the reflected light which is incident on a second prescribed area, the first and second prescribed areas being obtained by dividing the division element along at least one division line. A cross-section of the reflected light on the division element is a substantial circle having a
10   radius R. The division element is divided into four areas by two division lines substantially parallel to the tangent of the track of the information memory medium and away from a center of the substantial circle by a prescribed distance d and another division line passing through the center of
15   the substantial circle. Where a light collection point from the collection optical system is at a position away from the track by a prescribed distance with two areas among the four areas which are out of contact with each other being the first prescribed area, and the other two areas being
20   collectively the second prescribed area, information recorded on the track is obtained by the information reproduction signal generator, the prescribed distance d being shorter than the radius R.

25   In one embodiment of the invention, the division element is divided into at least five areas by a transverse division line which is substantially vertical to the tangent of the track of the information memory medium, a first longitudinal division line which is substantially parallel
30   to the tangent of the track and away from the center of the substantial circle by the prescribed distance d, a second longitudinal division line which is substantially parallel to the tangent of the track and away from the center of the

substantial circle by the prescribed distance d opposite
from the first longitudinal division line, and a third
longitudinal division line passing through the center of
the substantial circle; an area surrounded by the first
longitudinal division line and the transverse division line
is defined as area A, an area surrounded by the first
longitudinal division line, the third longitudinal division
line and the transverse division line is defined as area
B, an area surrounded by the second longitudinal division
line, the third longitudinal division line and the
transverse division line is defined as area C, an area
surrounded by the second longitudinal division line and the
transverse division line is defined as area D, the area A
and the area C are collectively the first prescribed area,
and the area B and the area D are collectively the second
prescribed area.

According to still another aspect of the invention,
a method for processing information stored on an information
memory medium includes the steps of emitting at least one
of a coherent beam and a quasi-monochromatic beam;
collecting the beam emitted by a light source to an
information memory medium having a track having at least
one of a mark and a space selectively arranged; receiving
the beam reflected by the information memory medium by a
plurality of detection areas and outputting a signal in
accordance with an amount of the beam received; dividing
the beam reflected by the information memory medium;
receiving a signal obtained in accordance with the reflected
beam incident on a first prescribed area and the reflected
beam incident on a second prescribed area and outputting
either one of the signals, the first and second prescribed
areas being obtained by dividing by the step of dividing;

and reproducing information recorded on the track based on
the signal obtained by the step of switching. The step of
switching includes the step of switching the signal to be
output in accordance with a positional relationship between
a light collection point obtained by the step of collecting
and the track.

According to still another aspect of the invention,
a method for processing information stored on an information
memory medium includes the steps of emitting at least one
of a coherent beam and a quasi-monochromatic beam;
collecting the beam emitted by a light source to an
information memory medium having a track having at least
one of a mark and a space selectively arranged; receiving
the beam reflected by the information memory medium by a
plurality of detection areas and outputting a signal in
accordance with an amount of the beam received; dividing
the beam reflected by the information memory medium;
reproducing information recorded on the track based on a
differential signal obtained in accordance with the
reflected beam which is incident on a first prescribed area
and the reflected beam which is incident on a second
prescribed area, the first and second prescribed areas being
obtained by the step of dividing, and changing a region
included in at least one of the first prescribed area and
the second prescribed area in accordance with a positional
relationship between a light collection point obtained by
the step of collecting and the track.

According to still another aspect of the invention,
an optical head device includes   a light source for
emitting at least one of a coherent beam and a quasi-
monochromatic beam; a collection optical system for

collecting the beam emitted by the light source to an
information memory medium having a track which has at least
one mark and at least one space; a light detector having
a plurality of detection areas for receiving the beam
reflected by the information memory medium and outputting
a signal in accordance with a light amount of the beam
received; and a tracking error signal generator for
receiving the signals output from the light detector and
generating a tracking error signal based on the signals.
The tracking error signal generator reduces a difference
between a first signal amplitude and a second signal
amplitude. The first signal amplitude is an absolute value
of a difference between a first signal level and a second
signal level. The second signal amplitude is an absolute
value of a difference between the first signal level and
a third signal level. The first signal level is a value of
the tracking error signal obtained when the beam emitted
by the light source is radiated to a center of the track.
The second signal level is a maximum value of the tracking
error signal obtained when the information memory medium
is scanned by the beam emitted by the light source in a
direction perpendicular to the track. The third signal
level is a minimum value of the tracking error signal
obtained when the information memory medium is scanned by
the beam emitted by the light source in a direction
perpendicular to the track.

According to still another aspect of the invention,
an optical head device includes a light source for emitting
at least one of a coherent beam and a quasi-monochromatic
beam; a collection optical system for collecting the beam
emitted by the light source to an information memory medium
having at least one track, at least one mark and at least

one space; a light detector having a plurality of detection
areas for receiving the beam reflected by the information
memory medium and outputting a signal in accordance with
a light amount of the beam received; a tracking error signal

5   generator for receiving the signals output from the light
detector and generating a tracking error signal based on
the signals. The tracking error generator subtracts, from
the tracking error signal, a component of the signal obtained
from an overlapping area. In the case where an aperture of

10   the collection optical system is a circle having a radius
of 1, the overlapping area is an area where two circles
overlap, the circles each having a radius of 1 and being
centered around a point which is $\lambda/(NA \cdot Gp)$ away, in a
direction perpendicular to the track, from a center of the

15   aperture, where λ is the wavelength of the beam emitted by
the light source, NA is the numerical aperture of the
collection optical system, Gp is the distance between
centers of two adjacent tracks of the information memory
medium, and $\lambda/(NA \cdot Gp) < 1$.

20

        According to still another aspect of the invention,
an optical head device includes a light source for emitting
at least one of a coherent beam and a quasi-monochromatic
beam; a collection optical system for collecting the beam

25   emitted by the light source to an information memory medium
having at least one track, at least one mark and at least
one space; a light detector having a plurality of detection
areas for receiving the beam reflected by the information
memory medium and outputting a signal in accordance with

30   a light amount of the beam received; a tracking error signal
generator for receiving the signals output from the light
detector and generating a tracking error signal based on
the signals; and a light division element for dividing an

overlapping area of the reflected beam and the vicinity thereof so as to be received by the light detector. The vicinity of the overlapping area refers to an area which is distanced from the overlapping area by a prescribed distance. In the case where an aperture of the collection optical system is a circle having a radius of 1, the overlapping area is an area where two circles overlap, the circles each having a radius of 1 and being centered around a point which is $\lambda/(NA\cdot Gp)$ away, in a direction perpendicular to the track, from a center of the aperture, where λ is the wavelength of the beam emitted by the light source, NA is the numerical aperture of the collection optical system, Gp is the distance between centers of two adjacent tracks of the information memory medium, and $\lambda/(NA\cdot Gp)<1$.

In one embodiment of the invention, the tracking error signal generator generates a tracking error signal using a signal obtained from the detection area which receives a beam in an area excluding the overlapping area, the beam being included in the reflected beam.

In one embodiment of the invention, the light division element includes at least two division lines which are substantially parallel to the tracks. The at least two division lines are arranged so as to sandwich the overlapping area of the reflected beam therebetween, and the tracking error signal generator generates a tracking error signal based on an operation of a signal obtained from the detection area which receives a beam incident on an area outside the at least two division lines, the beam being included in the reflected beam.

In one embodiment of the invention, the tracking
error signal generator corrects a tracking error signal
using a signal obtained from the detection area which
receives a beam in the overlapping area and the vicinity
5   thereof, the beam being included in the reflected beam.

In one embodiment of the invention, the light
division element includes division lines in the number of
N which are substantially parallel to the tangent to the
10   tracks, wherein N is an odd integer of 3 or more. The two
of the division lines are arranged so as to sandwich the
overlapping area of the reflected beam therebetween. The
remaining division lines are arranged between the two of
the division lines. The tracking error signal generator
15   generates a tracking error signal using signals obtained
from the detection area which receives a beam incident on
a first area and a second area which are outside the two
of the division lines and exclude the overlapping area, the
beam being included in the reflected beam. The tracking
20   error signal generator further generates a correction signal
by alternately inverting the polarity of signals obtained
from the detection area which receives a beam incident on
an even number of areas sandwiched between the two of the
division lines, the beam being included in the reflected
25   beam, and then adding together the signals obtained from
the detection area. The tracking error signal generator
then adds the tracking error signal and the correction signal
or subtracts the correction signal from the tracking error
signal.
30

In one embodiment of the invention, the light
division element includes division lines in the number of
N which are substantially parallel to the tangent to the

tracks, wherein N is an odd integer of 3 or more. The two
of the division lines are arranged so as to sandwich the
overlapping area therebetween. The remaining division
lines are arranged between the two of the division lines.
5   The tracking error signal generator generates a correction
signal by multiplying a value of each of the signals with
a prescribed value, the signals being obtained from the
detection area which receives a beam incident on an even
number of areas sandwiched between the two of the division
10   lines, the beam being included in the reflected beam, and
then alternately inverting the polarity of the resultant
signals, and adding together those signals. The tracking
error signal generator then adds the tracking error signal
and the correction signal or subtracts the correction signal
15   from the tracking error signal.

In one embodiment of the invention, the light
division element is a holographic element.

20   In one embodiment of the invention, the light
division element is integral with a collection optical
system.

In one embodiment of the invention, the light
25   division element is a division line of the light detector.

According to still another aspect of the invention,
an optical head device includes a light source for emitting
at least one of a coherent beam and a quasi-monochromatic
30   beam; a collection optical system for collecting the beam
emitted by the light source to an information memory medium
having at least one track, at least one mark and at least
one space; a light detector having a plurality of detection

areas for receiving the beam reflected by the information memory medium and outputting a signal in accordance with a light amount of the beam received; a tracking error signal generator for receiving the signals output from the light detector and generating a tracking error signal based on the signals; and a light reduction element provided on a beam path for reducing the light transmittance of the overlapping area and the vicinity thereof. In the case where an aperture of the collection optical system is a circle having a radius of 1, the overlapping area is an area where two circles overlap, the circles each having a radius of 1 and being centered around a point which is $\lambda/(NA \cdot Gp)$ away, in a direction perpendicular to the track, from a center of the aperture, where λ is the wavelength of the beam emitted by the light source, NA is the numerical aperture of the collection optical system, Gp is the distance between centers of two adjacent tracks of the information memory medium, and $\lambda/(NA \cdot Gp)<1$.

In one embodiment of the invention, the light reduction element is integral with the collection optical system.

In one embodiment of the invention, the light reduction element is a holographic element.

According to still another aspect of the invention, an optical head device includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic beam; an optical element for receiving the beam emitted by the light source and dividing the beam into first beam and a second beam an effective numerical aperture of the collection optical system with respect to the first beam

being different from an effective numerical aperture of the
collection optical system with respect to the second beam;
a collection optical system for receiving the first beam
and the second beam and converging the first and second beams
5   into a microscopic spot on an information memory medium;
a beam branching element for receiving the beam diffracted
and/or reflected by the information memory medium and
branching the beam; a light detector for receiving the
branched beam and outputting a signal in accordance with
10   a light amount of the beam received; a signal processing
section for receiving the signal from the light detector
and performing an operation of the signal; a driving section
for determining relative positions of the collection optical
system and the information memory medium based on the signal
15   output from the signal processing section; and a tracking
error signal generator for generating a tracking error
signal using the first or second beam with respect to which
the effective numerical aperture of the collection optical
system is smaller.

20

     In one embodiment of the invention, the information
memory medium includes marks or prescribed grooves for
realizing detection of the tracking error signal, where Gp
is the cycle of the marks or grooves, and NA is the numerical
25   aperture of the collection optical system, the first beam
has a wavelength λ represented by $Gp>\lambda/NA$, and the second
beam has a wavelength λ represented by $Gp<\lambda/NA$, and the
tracking error signal generator generates a tracking error
signal based on the second beam. In this specification, the
30   cycle of the grooves refers to the distance between the
center of one groove and the center of a groove adjacent
thereto.

In one embodiment of the invention, an optical axis of the first beam is substantially coincident with an optical axis of the second beam.

5   In one embodiment of the invention, the optical element is a polarization filter.

In one embodiment of the invention, the optical element is integral with the collection optical system.

10

According to still another aspect of the invention, an inclination detection apparatus includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic beam; a collection optical system for 15   receiving the beam emitted by the light source and converging the beam into a microscopic spot on an information memory medium; a beam branching element for receiving the beam diffracted and/or reflected by the information memory medium and branching the beam; a light detector for receiving the 20   branched beam and outputting a signal in accordance with a light amount of the beam received; a signal processing section for receiving the signal from the light detector and performing an operation of the signal; and a driving section for performing focusing control and tracking control 25   to determine relative positions of the collection optical system and the information memory medium. The light detector includes a plurality of detection areas. The information memory medium has a first pattern area including a mark and a space and a second pattern area including 30   prescribed grooves. The first pattern area and the second pattern area are alternately arranged on the information memory medium. The signal processing section detects an angle made by the beam collected by the collection optical

system and the information memory medium, using a signal obtained by the light detector when one of the first pattern area and the second pattern area is irradiated by the beam collected by the collection optical system.

In one embodiment of the invention, in the case where the mark and the space in the first pattern area are irradiated by the beam collected by the collection optical system, tracking control is performed using the signal obtained by the light detector. In the case where the second pattern area is irradiated by the beam collected by the collection optical system, the angle made by the beam collected by the collection optical system and the information memory medium is detected using a signal obtained by the light detector.

In one embodiment of the invention, in the case where the second pattern area is irradiated by the beam collected by the collection optical system, tracking control is performed using the signal obtained by the light detector. In the case where the first pattern area is irradiated by the beam collected by the collection optical system, the angle made by the beam collected by the collection optical system and the information memory medium is detected using a signal obtained by the light detector.

In one embodiment of the invention, in the case where the mark and the space of the first pattern area are irradiated by the beam collected by the collection optical system, the angle made by the beam collected by the collection optical system and the information memory medium is detected using a signal obtained by the light detector.

In one embodiment of the invention, the inclination detection apparatus has the relationship of $NA > \lambda/Gp$ where Gp is the cycle of marks in the first pattern area or the cycle of the grooves in the second pattern area, λ is the

5   wavelength of the beam emitted by the light source, and NA is the numerical aperture of a part of the collection optical system facing the information memory medium.

According to still another aspect of the invention,

10   an optical information processing apparatus includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic beam; a collection optical system for receiving the beam emitted by the light source and converging the beam into a microscopic spot on an information memory

15   medium; a beam branching element for receiving the beam diffracted and/or reflected by the information memory medium and branching the beam; a light detector for receiving the branched beam and outputting a signal in accordance with a light amount of the beam received; a signal processing

20   section for receiving the signal from the light detector and performing an operation of the signal; a first driving section for performing focusing control and tracking control to determine relative positions of the collection optical system and the information memory medium; and a second

25   driving section for changing the angle made by the beam collected by the collection optical system and the information memory medium. The light detector includes a plurality of detection areas. The information memory medium has patterns or prescribed grooves for generating

30   a tracking error signal. $NA > \lambda/Gp$ where Gp is the cycle of patterns or grooves, λ is the wavelength of the beam emitted by the light source, and NA is the numerical aperture of a part of the collection optical system facing the

information memory medium.

According to still another aspect of the invention, an optical information prossing apparatus includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic beam; a collection optical system for receiving the beam emitted by the light source and converging the beam into a microscopic spot on an information memory medium; a beam branching element for receiving the beam diffracted and/or reflected by the information memory medium and branching the beam; a light detector for receiving the branched beam and outputting a signal in accordance with a light amount of the beam received; a signal processing section for receiving the signal from the light detector and performing an operation of the signal; a first driving section for performing focusing control and tracking control to determine relative positions of the collection optical system and the information memory medium; and a second driving section for changing the angle made by the beam collected by the collection optical system and the information memory medium. The light detector includes a plurality of detection areas. The information memory medium has a first pattern area including a mark and a space and a second pattern area including prescribed grooves. The first pattern area and the second pattern area are alternately arranged on the information memory medium. The signal processing section detects an angle made by the beam collected by the collection optical system and the information memory medium, using a signal obtained by the light detector, and also generates a signal for driving the second driving section, when one of the first pattern area and the second pattern area is irradiated by the beam collected by the collection optical system.

In one embodiment of the invention, in the case where
the mark in the first pattern area is irradiated by the beam
collected by the collection optical system, tracking control
5   is performed using the signal obtained by the light detector.
In the case where the second pattern area is irradiated by
the beam collected by the collection optical system, the
angle made by the beam collected by the collection optical
system and the information memory medium is detected using
10   a signal obtained by the light detector.

In one embodiment of the invention, in the case where
the second pattern area is irradiated by the beam collected
by the collection optical system, tracking control is
15   performed using the signal obtained by the light detector.
In the case where the first pattern area is irradiated by
the beam collected by the collection optical system, the
angle made by the beam collected by the collection optical
system and the information memory medium is detected using
20   a signal obtained by the light detector.

In one embodiment of the invention, in the case where
the mark and the space of the first pattern area are
irradiated by the beam collected by the collection optical
25   system, the angle made by the beam collected by the
collection optical system and the information memory medium
is detected using a signal obtained by the light detector.

In one embodiment of the invention, the optical
30   information prossing apparatus has the relationship of
$NA > \lambda / Gp$ where Gp is the cycle of marks in the first pattern
area or the cycle of the grooves in the second pattern area,
λ is the wavelength of the beam emitted by the light source,

and NA is the numerical aperture of a part of the collection optical system facing the information memory medium.

According to still another aspect of the invention, an optical head device includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic beam; a collection optical system for collecting the beam emitted by the light source to an information memory medium having a track which has at least one mark and at least one space selectively arranged; a light detector for receiving the beam reflected by the information memory medium and outputting a signal in accordance with a light amount of the beam received; a light division element for dividing the beam reflected by the information memory medium so as to be received by the light detector; an information reproduction signal generator for generating an information reproduction signal for reproducing information stored in the track, based on a signal indicating the difference between the beams incident on a first area and a second area defined by a division line of the light division element; and a changing element for changing a region included in the first area, a region included in the second area, or a region included in both the first area and the second area in accordance with the positional relationship between the light collection point of the light from the collection optical system and the track.

In one embodiment of the invention, in the case where the beam has a substantially circular cross section having a radius of 1 on the light division element, the light division element is divided into three areas by a first division line which is substantially parallel to the tangent to the track and is distanced from the center of the

substantially circular cross section by a prescribed distance d, and a second division line which is substantially parallel to the tangent to the track and is distanced from the center of the substantially circular cross section by the prescribed distance d in an opposite direction to the first division line; the area which is outside the first division line and thus excludes the center of the substantially circular cross section may be defined as area A, the area sandwiched by the first division line and the second division line may be defined as area B, and the area which is outside the second division line and thus excludes the center of the substantially circular cross section may be defined as area C. When the light collection point from the collection optical system is at a first position on the information memory medium which is distanced in one direction from the track by a prescribed distance, the information reproduction signal generator generates an information reproduction signal for reproducing information stored in the information memory medium, with the area A being the first area and a sum of the areas B and C being the second area. When the light collection point from the collection optical system is at a second position on the information memory medium which is distanced from the track by the prescribed distance in an opposite direction to the first position, the information reproduction signal generator generates an information reproduction signal for reproducing information stored in the track, with a sum of the areas A and B being the first area and the area C being the second area.

In one embodiment of the invention, where the beam has a substantially circular cross section having a radius of 1 on the light division element, the light division

element is divided into four areas by a first division line
which is substantially parallel to the tangent to the track
and is distanced from the center of the substantially
circular cross section by a prescribed distance d, a second
division line which is substantially parallel to the tangent
to the track and is distanced from the center of the
substantially circular cross section by the prescribed
distance d in an opposite direction to the first division
line, and a third division line which is substantially
parallel to the tangent to the track and runs through the
center of the substantially circular cross section; the area
which is outside the first division line and thus excludes
the center of the substantially circular cross section may
be defined as area A, the area sandwiched by the first
division line and the third division line may be defined
as area B, the area sandwiched by the third division line
and the second division line may be defined as area C, and
the area which is outside the second division line and thus
excludes the center of the substantially circular cross
section may be defined as area D. When the light collection
point from the collection optical system is at a first
position on the information memory medium which is distanced
in one direction from the track by a prescribed distance,
the information reproduction signal generator generates an
information reproduction signal for reproducing
information stored in the information memory medium, with
the area A being the first area and the area C and D being
the second area. When the light collection point from the
collection optical system is at a second position on the
information memory medium which is distanced from the track
by the prescribed distance in an opposite direction to the
first position, the information reproduction signal
generator generates an information reproduction signal for

reproducing information stored in the track, with the areas A and B being the first area and the area D being the second area.

5   According to still another aspect of the invention, an optical head device includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic beam; a collection optical system for collecting the beam emitted by the light source to an information memory medium

10   having a track which has at least one mark and at least one space selectively arranged; a light detector having a plurality of detection areas for receiving the beam reflected by the information memory medium and outputting a signal in accordance with a light amount of the beam

15   received; a light division element for dividing the beam reflected by the information memory medium so as to be received by the light detector; and an information reproduction signal generator for generating an information reproduction signal for reproducing information stored in

20   the track, based on a signal indicating the difference between the beams incident on a first area and a second area defined by a division line of the light division element. In the case where the beam has a substantially circular cross section having a radius of 1 on the light division element,

25   the light division element is divided into three areas by a first division line which is substantially parallel to the tangent to the track and is distanced from the center of the substantially circular cross section by a prescribed distance d, and a second division line which is substantially

30   parallel to the tangent to the track and is distanced from the center of the substantially circular cross section by the prescribed distance d in an opposite direction to the first division line, one of the areas excluding the center

of the substantially circular cross section may be defined
as the first area, and another area excluding the center
of the substantially circular cross section may be defined
as the second area. When the light collection point from
5   the collection optical system is at a position on the
information memory medium which is distanced from the track
by a prescribed distance, the information reproduction
signal generator generates an information reproduction
signal for reproducing information stored in the track.
10

According to still another aspect of the invention,
an optical head device includes a light source for emitting
one of a coherent beam or a quasi-monochromatic beam; a
collection optical system for collecting the beam emitted
15   by the light source to an information memory medium having
a track which has at least one mark and at least one space
selectively arranged; a light detector having a plurality
of detection areas for receiving the beam reflected by the
information memory medium and outputting a signal in
20   accordance with a light amount of the beam received; a light
division element for dividing the beam reflected by the
information memory medium so as to be received by the light
detector; and an information reproduction signal generator
for generating an information reproduction signal for
25   reproducing information stored in the track, based on a
signal indicating the difference between the beams inci
on a first area and a second area defined by a division line
of the light division element. In the case where the beam
has a substantially circular cross section having a radius
30   of 1 on the light division element, the light division
element is divided into four areas by a first division line
which is substantially parallel to the tangent to the track
and is distanced from the center of the substantially

circular cross section by a prescribed distance d, a second division line which is substantially parallel to the tangent to the track and is distanced from the center of the substantially circular cross section by the prescribed distance d in an opposite direction to the first division line, and a third division line which is substantially parallel to the tangent to the track and runs through the center of the substantially circular cross section, a sum of the area which is outside the first division line and thus excludes the center of the substantially circular cross section and the area sandwiched by the third division line and the second division line may be defined as the first area, and a sum of the area sandwiched by the first division line and the third division line and the area which is outside the second division line and thus excludes the center of the substantially circular cross section may be defined as a second area. When the light collection point from the collection optical system is at a position on the information memory medium which is distanced from the track by a prescribed distance, the information reproduction signal generator generates an information reproduction signal for reproducing information stored in the track.

In one embodiment of the invention, in the case where the beam has a substantially circular cross section having a radius of 1 on the light division element, the distance d between the center of the substantially circular cross section and each of the first division line and the second division line is 0.1 or more and 0.3 or less.

According to still another aspect of the invention, an optical head device includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic

beam; a collection optical system for collecting the beam emitted by the light source to an information memory medium having tracks having a mark and a space selectively arranged or tracks having prescribed grooves; a light detector having

5   a plurality of detection areas for receiving the beam reflected by the information memory medium and outputting a signal in accordance with a light amount of the beam received; a tracking error signal generator for receiving the signals from the light detector and generating a tracking

10   error signal based on the signals received; and a light division element for dividing the beam reflected by the information memory medium so as to be received by the light detector. Where λ is the wavelength of the beam emitted by the light source, NA is the numerical aperture of the

15   collection optical system, Gp is the distance between centers of two adjacent tracks of the information memory medium, $\lambda/(NA \cdot Gp) \geq 1$, and the beam has a substantially circular cross section having a radius of 1 on the light division element. The light division element has at least

20   five division lines which are substantially parallel to the tangent to the tracks. Where the division line running through the center of the substantially circular cross section is a first division line, two division lines which are distanced from the first division line by a distance

25   of about 0.1 in two opposite directions are a second division line and a third division line, and two division lines which are distanced from two ends of the cross section by a distance of about 0.1 are a fourth division line and a fifth division line. The tracking error signal generator

30   generates the tracking error signal by alternately inverting the polarity of the signals obtained in accordance with the beams incident on six areas defined by the five division lines and adding together those signals.

According to still another aspect of the invention, an optical head device includes a light source for emitting at least one of a coherent beam and a quasi-monochromatic beam; a collection optical system for collecting the beam emitted by the light source to an information memory medium having tracks having a mark and a space selectively arranged or tracks having prescribed grooves; a light detector having a plurality of detection areas for receiving the beam reflected by the information memory medium and outputting a signal in accordance with a light amount of the beam received; a tracking error signal generator for receiving the signals from the light detector and generating a tracking error signal based on the signals received; and a light division element for dividing the beam reflected by the information memory medium so as to be received by the light detector. Where λ is the wavelength of the beam emitted by the light source, NA is the numerical aperture of the collection optical system, Gp is the distance between centers of two adjacent tracks of the information memory medium, $\lambda/(NA \cdot Gp) \geq 1$, and an aperture of the collection optical system is a circle having a radius of 1. The light division element has division lines in the number of N which are substantially parallel to the tangent to the tracks, where N is an odd integer of 3 or more. The two of the division lines are positioned within a width of about 0.6 from the center of the aperture of the collection optical system. The remaining division lines are positioned between the two division lines at an equal interval. The tracking error signal generator generates the tracking error signal using signals obtained from the areas which are outside the two division lines and thus exclude the center of the substantially circular cross section. The tracking error

signal generator generates a correction signal by
alternately inverting the polarity of signals obtained from
an even number of areas sandwiched by the two division lines
and adding together those signals. The tracking error
5   signal generator adds the tracking error signal and the
correction signal or subtracts the correction signal from
the tracking error signal.

In one embodiment of the invention, the line
10   division element is a diffraction element.

In one embodiment of the invention, the line
division element is a division line of the light detector.

15   According to still another aspect of the invention,
an optical head device includes a light source for emitting
at least one of a coherent beam and a quasi-monochromatic
beam; a collection optical system for collecting the beam
emitted by the light source to an information memory medium
20   having tracks having a mark and a space selectively arranged
or tracks having prescribed grooves; a diffraction element
for receiving a beam diffracted by the information memory
medium and generating a diffraction beam; and a light
detector having a plurality of detection areas for receiving
25   the beam diffracted by the diffraction element and
outputting a signal in accordance with a light amount of
the beam received. The diffraction element includes a
plurality of areas. A diffraction beam of a desired order
generated by an area group A included in the plurality of
30   areas form a first spherical wave. A diffraction beam of
a desired order generated by an area group B included in
the plurality of areas but excluded from the area group A
form a second spherical wave, which has a light collection

point farther than the light collection point of the first
spherical wave with respect to the diffraction element. A
focusing error signal generator is provided for generating
a focusing error signal based on the difference between the
5   cross sections of the first spherical wave and the second
spherical wave on the light detector. The diffraction
element has at least one division line perpendicular to the
tangent to the tracks. Either one of portions sandwiching
the at least one division line is included in the area group
10   A and the other portion is included in the area group B.

According to still another aspect of the invention,
an optical head device includes a light source for emitting
at least one of a coherent beam and a quasi-monochromatic
15   beam; a collection optical system for collecting the beam
emitted by the light source to an information memory medium
having tracks having a mark and a space selectively arranged
or tracks having prescribed grooves; a diffraction element
for receiving a beam diffracted by the information memory
20   medium and generating a diffraction beam; and a light
detector having a plurality of detection areas for receiving
the beam diffracted by the diffraction element and
outputting a signal in accordance with a light amount of
the beam received. The diffraction element includes a
25   plurality of areas. A diffraction beam of a desired order
generated by an area group A included in the plurality of
areas form a first spherical wave. A diffraction beam of
a desired order generated by an area group B included in
the plurality of areas but excluded from the area group A
30   form a second spherical wave, which has a light collection
point farther than the light collection point of the first
spherical wave with respect to the diffraction element. A
focusing error signal generator is provided for generating

a focusing error signal based on the difference between the cross sections of the first spherical wave and the second spherical wave on the light detector. The diffraction element has a diffraction area which is larger than the area

5   corresponding to an aperture of the collection optical system. The diffraction element has a first division line and a second division line interposing the aperture, the first division line and the second division line being parallel to the tangent to the tracks and in contact with

10   an outer periphery of the aperture. Either one of portions sandwiching the first division line or the second division line is included in the area group A and the other portion is included in the area group B.

15   In one embodiment of the invention, the diffraction element is integral with the collection optical system.

According to still another aspect of the invention, a method for processing optical information includes the

20   steps of emitting at least one of a coherent beam and a quasi-monochromatic beam; collecting the beam emitted by the light source to an information memory medium having at least one track, at least one mark and at least one space; receiving the beam reflected by the information memory

25   medium by a plurality of detection areas and outputting a signal in accordance with a light amount of the beam received; and receiving the signals output from the plurality of detection areas and generating a tracking error signal based on the signals. The step of generating a

30   tracking error signal includes the step of subtracting a component of the signal obtained from an overlapping area from the tracking error signal. In the case where an aperture of a collection optical system for collecting the

beam is a circle having a radius of 1, the overlapping area is an area where two circles overlap, the circles each having a radius of 1 and being centered around a point which is $\lambda/(NA \cdot Gp)$ away, in a direction perpendicular to the track, from a center of the aperture of the collection optical system, and where λ is the wavelength of the emitted beam, NA is the numerical aperture of the collection optical system, and Gp is the distance between centers of two adjacent tracks of the information memory medium, $\lambda/(NA \cdot Gp)<1$.

According to still another aspect of the invention, a method for processing optical information includes the steps of emitting at least one of a coherent beam and a quasi-monochromatic beam; receiving the beam emitted by the light source and dividing the beam into a first beam and a second beam; receiving the first beam and the second beam and collecting the first beam and the second beam into a microscopic spot on an information memory medium, an effective numerical aperture of the collection optical system for collecting the beams with respect to the first beam being different from an effective numerical aperture of the collection optical system with respect to the second beam; receiving the beam diffracted and/or reflected by the information memory medium and branching the beam; receiving the branched beam and outputting a signal in accordance with a light amount of the beam received; receiving the output signal and performing an operation of the signal; determining relative positions of the collection optical system and the information memory medium based on the signal obtained as a result of the operation; and generating a tracking error signal using the first or second beam with respect to which the effective numerical aperture of the collection optical system is smaller.

According to still another aspect of the invention, a method for processing optical information includes the steps of emitting at least one of a coherent beam and a quasi-monochromatic beam; receiving the beam emitted by the light source and converging the beam into a microscopic spot on an information memory medium; receiving the beam diffracted and/or reflected by the information memory medium and branching the beam; receiving the branched beam by a plurality of detection areas and outputting a signal in accordance with a light amount of the beam received; receiving the output signal and performing an operation of the signal; performing focusing control and tracking control to determine relative positions of a collection optical system for converging the beam and the information memory medium; and changing the angle made by the beam converged by the collection optical system and the information memory medium. The information memory medium has patterns or prescribed grooves for generating a tracking error signal, and NA>λ/Gp where Gp is the cycle of the patterns or grooves, λ is the wavelength of the emitted beam, and NA is the numerical aperture of a part of the converging system facing the information memory medium.

According to still another aspect of the invention, a method for processing optical information includes the steps of emitting at least one of a coherent beam and a quasi-monochromatic beam; collecting the beam emitted by the light source to an information memory medium having a track having a mark and a space selectively arranged; receiving the beam reflected by the information memory medium by a plurality of detection areas and outputting a signal in accordance with a light amount of the beam

received; dividing the light reflected by the information memory medium; generating an information reproduction signal for reproducing information stored in the track based on a signal indicating the difference between a signal
5   obtained in accordance with the beams incident on a first area and a second area obtained as a result of dividing the light; and changing a region included in the first area, a region included in the second area, or a region included in both the first area and the second area, in accordance
10 with the positional relationship between the light collection point of the light from a collection optical system for collecting the beam and the track.

According to still another aspect of the invention,
15 a method for processing optical information includes the steps of emitting at least one of a coherent beam and a quasi-monochromatic beam; collecting the beam emitted by the light source to an information memory medium having tracks having a mark and a space selectively arranged or
20 tracks having prescribed grooves; receiving the beam reflected by the information memory medium by a detection area and outputting a signal in accordance with a light amount of the beam received; receiving the output signal and generating a tracking error signal based on the signal
25 received; and dividing the light reflected by the information memory medium. Where λ is the wavelength of the emitted beam, NA is the numerical aperture of a collection optical system for collecting the beam, Gp is the distance between centers of two adjacent tracks of the information
30 memory medium, $\lambda/(NA \cdot Gp) \geq 1$, and the beam has a substantially circular cross section having a radius of 1, the light division element has at least five division lines which are substantially parallel to the tangent to the tracks; the

division line running through the center of the substantially circular cross section may be defined as a first division line, two division lines which are distanced from the first division line by a distance of about 0.1 in

5   two opposite directions may be defined as a second division line and a third division line, and two division lines which are distanced from two ends of the cross section by a distance of about 0.1 may be defined as a fourth division line and a fifth division line. The method further includes

10   the step of generating the tracking error signal by alternately inverting the polarity of the signals obtained in accordance with the beams incident on six areas defined by the five division lines and adding together those signals.

15   According to still another aspect of the invention, a method for processing optical information includes the steps of emitting at least one of a coherent beam and a quasi-monochromatic beam; collecting the beam emitted by the light source to an information memory medium having

20   tracks having a mark and a space selectively arranged or tracks having prescribed grooves; receiving the beam reflected by the information memory medium by a plurality of areas and generating a diffraction beam; receiving the diffracted beam by a plurality of detection areas and

25   outputting a signal in accordance with a light amount of the beam received; and generating a focusing error signal based on the difference between the size of the cross section of a first spherical wave and the size of the cross section of a second spherical wave. The first spherical wave

30   corresponds to a diffraction beam of a desired order generated by an area group A included in the plurality of areas. The second spherical wave corresponds to a diffraction beam of a desired order generated by an area

group B included in the plurality of areas but excluded from
the area group A. Either one of portions sandwiching the
at least one division line is included in the area group
A and the other portion is included in the area group B.

Thus, the invention described herein makes possible
the advantages of (1) providing an optical head device
having stable servo characteristics and thus realizes stable
formation of marks at appropriate positions on or in the
vicinity of the tracks for information recording, and also
realizes correct information reproduction and stable
information recording and erasure with a sufficiently low
error ratio; (2) providing an inclination detection
apparatus for detecting an inclination of 0.5 degrees or
less with high precision; and (3) an optical information
processing apparatus for realizing stable information
recording to and reproduction from an information memory
medium which is significantly curved.

These and other advantages of the present invention
will become apparent to those skilled in the art upon reading
and understanding the following detailed description with
reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of an optical system
of an optical head device according to the present invention;

Figure 2 shows detection areas of a light detector
of the optical head device shown in Figure 1, and a
configuration of a circuit acting as an information
reproduction signal generator and a tracking error signal

generator;

Figure **3** is a graph illustrating the tracking error
signal vs. off-track amount relationship of the optical head
5   device shown in Figure **2**;

Figure **4** shows a light detector usable in the optical
head device shown in Figure **1** having different detection
areas from the light detector shown in Figure **2**, and a
10   configuration of a circuit acting as an information
reproduction signal generator and a tracking error signal
generator;

Figure **5** shows a light detector usable in the optical
15   head device shown in Figure **1** having different detection
areas from the light detector shown in Figure **2**;

Figure **6** shows a light detector usable in the optical
head device shown in Figure **1** having different detection
20   areas from the light detector shown in Figure **2**;

Figure **7** shows a light detector usable in the optical
head device shown in Figure **1** having different detection
areas from the light detector shown in Figure **2**, and a
25   configuration of a circuit acting as a tracking error signal
generator;

Figure **8** shows a light detector usable in the optical
head device shown in Figure **1** having different detection
30   areas from the light detector shown in Figure **2**, and a
configuration of a circuit acting as a tracking error signal
generator;

Figure **9** shows a light detector usable in the optical head device shown in Figure **1** having different detection areas from the light detector shown in Figure **2**, and a configuration of a circuit acting as a tracking error signal
5   generator;

Figure **10A** is a schematic view of an optical system, using a light reducing element, of an optical head device according to the present invention;
10

Figure **10B** is a front view of an objective lens usable in the optical system shown in Figure **10A**;

Figure **11** is a schematic view of an optical system,
15   using another light reducing element, of an optical head device according to the present invention;

Figure **12** is a schematic view of an optical system, using still another light reducing element, of an optical
20   head device according to the present invention;

Figure **13** is a schematic view of an optical system, using still another light reducing element, of an optical head device according to the present invention;
25

Figure **14** is a schematic view of an optical system of an optical head device according to the present invention;

Figure **15** shows a relationship among a pattern for
30   dividing a holographic element, detection areas of the light detector, and the cross section of the diffraction light on the light detector in the optical head device shown in Figure **14**;

Figure **16** shows another pattern for dividing a holographic element;

5   Figure **17** is a schematic view of an optical system of an optical head device according to the present invention;

Figure **18** shows detection areas of a light detector of the optical head device shown in Figure **17**, and a
10   configuration of a circuit acting as an information reproduction signal generator and a tracking error signal generator;

Figure **19A** shows a pattern of a groove, tracks and
15   pits of an information memory medium;

Figure **19B** shows detection areas of a light detector and a configuration of an information reproduction signal generator for producing information stored off the track
20   according to the present invention;

Figure **19C** shows different detection areas of a light detector and a configuration of an information reproduction signal generator for producing information
25   stored off the track according to the present invention;

Figure **20** shows detection areas of a light detector usable in the optical head device shown in Figure **17**, and a configuration of a circuit acting as an information
30   reproduction signal generator and a tracking error signal generator;

Figure **21A** shows a pattern of a groove, tracks and

pits of an information memory medium;

Figure **21B** shows detection areas of a light detector
and a configuration of an information reproduction signal
5   generator for producing information stored off the track
according to the present invention;

Figure **21C** shows different detection areas of a
light detector and a configuration of an information
10   reproduction signal generator for producing information
stored off the track according to the present invention;

Figure **22A** shows a pattern of a groove, tracks and
pits of an information memory medium;
15

Figure **22B** shows detection areas of a light detector
and a configuration of an information reproduction signal
generator for producing information stored off the track
according to the present invention;
20

Figure **23A** shows a pattern of a groove, racks and
pits of an information memory medium;

Figure **23B** shows detection areas of a light detector
25   and a configuration of an information reproduction signal
generator for producing information stored off the track
according to the present invention;

Figure **24** shows a relationship among a pattern for
30   dividing a holographic element, detection areas of the light
detector, and the cross section of the diffraction light
on the light detector in an optical head device according
to the present invention;

Figure **25** is a schematic view of an optical system of an optical head device according to the present invention;

5   Figure 26 shows a relationship among a pattern for dividing a holographic element, detection areas of the light detector, and the cross section of the diffraction light on the light detector in an optical head device according to the present invention;

10

Figure **27** shows another pattern for dividing a holographic element;

Figure **28** is a schematic view of an inclination

15   detection apparatus according to the present invention;

Figure **29** shows a configuration of a signal processing section of the inclination detection apparatus shown in Figure **28**;

20

Figure **30** shows a configuration of an information memory medium usable in the inclination detection apparatus shown in Figure **28**;

25   Figure **31A** is a schematic partial view of the track of the information memory medium shown in Figure **30**;

Figures **31B** through **31E** show waveforms of a signal which is output from different elements of the signal

30   processing section shown in Figure **29**;

Figure **32** is a graph illustrating the relationship between the inclination detection signal and the radial

inclination of the optical memory medium obtained in an inclination detection apparatus according to the present invention;

5   Figure **33** shows another configuration of a signal processing section usable in an inclination detection apparatus according to the present invention;

Figure **34** shows a configuration of an information
10   memory medium usable in an inclination detection apparatus according to the present invention;

Figure **35** shows still another configuration of a signal processing apparatus in an inclination detection
15   apparatus according to the present invention;

Figure **36** is a schematic view of an optical head device according to the present invention;

20   Figure **37** shows a polarization filter usable in the optical head device shown in Figure **36**;

Figure **38** shows a configuration of a signal processing section of the optical head device shown in Figure
25   **36**;

Figure **39** is a schematic view of an optical head device according to the present invention;

30   Figure **40** shows a schematic pattern of an off-axis fresnel zone plate formed on a holographic element usable in the optical head device shown in Figure **39**;

Figure **41** shows the relationship between detection areas of a light detector and beams in the optical head device shown in Figure **39**;

5   Figure **42** is a schematic view of an optical system of a conventional optical head device;

Figures **43A** through **43C** each show a pattern of light detection areas of a light detector and the shape of a cross 10   section of light detected by the detection areas in a conventional optical head device;

Figure **44** is a schematic view of a conventional inclination detection apparatus;

15

Figure **45** shows a configuration of a conventional information memory medium;

Figure **46** shows a configuration of a signal 20   processing section of a conventional inclination detection apparatus;

Figure **47** is a schematic view of another conventional optical head device;

25

Figure **48** shows a configuration of a signal processing section of a conventional optical head device;

Figure **49** shows a configuration of a conventional 30   information memory medium used in the optical head device shown in Figure **47**;

Figure **50** is a plot illustrating values of jitter

in the case where information stored off the track is reproduced using the light detector in the sixth example in which a division line is shifted from a center of the aperture;

5

Figure **51** shows a detection area of a light detector and a circuit configuration of a tracking error signal generator and an information reproduction signal generator of an optical head device according to the present invention;

10

Figures **52A** and **52B** represent the information reproduction signal generator of the optical head device shown in Figure **51** for reproducing information stored off the track;

15

Figure **53** is a plot illustrating values of jitter caused when information stored off the track is reproduced using the light detector, of the optical head device shown in Figure **51**, in which a division line is shifted from a

20   center of the aperture;

Figure **54** shows a detection area of a light detector and a circuit configuration of a tracking error signal generator and an information reproduction signal generator

25   of an optical head device in a sixteenth example according to the present invention;

Figure **55** is a plot illustrating values of jitter caused when information stored off the track is reproduced

30   using the light detector in the sixteenth example in which a division line is shifted from a center of the aperture;

Figures   **56A**   and   **56B**   represent   information

reproduction signal generators in optical head devices according to the present invention for reproducing information stored off the track:

5   Figures **57A** and **57B** represent other information reproduction signal generators of optical head devices according to the present invention for reproducing information stored off the track;

10   Figure **58** represents still another information reproduction signal generator of an optical head device according to the present invention for reproducing information stored off the track; and

15   Figure **59** represents yet another information reproduction signal generator of an optical head device according to the present invention for reproducing information stored off the track.

20   DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention will be described by way of examples with reference to the attached drawings. In the following examples, identical reference
25   numerals indicate elements having identical functions, respectively.

(Example 1)
         An optical head device according to a first example
30   of the present invention will be described with reference to Figures **1** through **3**.

Figure **1** is a schematic view of an optical system

of the optical head device.   The optical head device operates in the following manner.

5   Light emitted by a semiconductor laser 101 (used as a light source) is reflected by a plane-parallel beam splitter 102 and then collimated by a collimator lens 103, which is a part of the optical system.   The light is collected by an objective lens 104, which is also a part of the optical system, and then focused on an information layer 108 of an 10   optical disk 105 employed as an information memory medium. An actuator 107 moves the objective lens 104 and a holding device 106 for holding the objective lens 104 in accordance with the fluctuation or decentration of the optical disk 105.

15

The light is then diffracted and/or reflected by the information layer 108 of the optical disk 105 to light 108a, which is transmitted back through the objective lens 104 to be collimated.   The collimated light 108a is then 20   converged by the collimator lens 103.   The converged light 108a is provided with a non-point aberration when passing through the plane-parallel beam splitter 102.   The light after passing through the plane-parallel beam splitter 102 will be referred to as light 108a.   The converged light 108a 25   provided with the non-point aberration is detected by a light detector 150.   The optical system is arranged so that, when the focal point F0 of the light from the objective lens 104 is on the information layer 108 of the optical disk 105, the detection surface of the light detector 150 is at the 30   least circle of confusion of the converged light 108a.

The optical disk 105 serving as the information memory medium includes a plurality of grooves.   As shown in

Figure 1, the distance between the center of one of such grooves and the center of an adjacent groove is indicated by Gp. Information can be stored (1) either on the bottom of the groove or between the grooves, or (2) both on the bottom of the groove and between the grooves. Further in this specification, the numerical aperture of the objective lens 104 is indicated by NA, and the wavelength of the light emitted by the semiconductor laser 101 is indicated by λ.

In the first example, the optical head device which fulfills the conditions represented by expression (4) will be described.

$$\lambda/(NA \cdot Gp) < 1 \quad \dots \quad (4)$$

Figure 2 shows detection areas 201 through 208 of the light detector 150, an information reproduction signal generator 450, and a tracking error signal generator 451.

The light detector 150 is divided into detection areas 201 through 208 by division lines 301 through 304. Under the conditions represented by expression (4), plus first-order diffraction light and minus first-order diffraction light overlap each other at least partially. In Figure 2, the overlapping area 200 is indicated by hatching. The maximum value W of the width in the radial direction of the overlapping area 200 is:

$$W = 2 \cdot (1 - \lambda/(NA \cdot Gp)) \quad \dots \quad (5)$$

where the aperture of the optical system as shown in Figure 1 has a radius of 1.

The division lines **301** through **303** are parallel to the tangent to the grooves of the optical disk **105** (Figure **1**). The division line **304** is perpendicular to the tangent to the grooves of the optical disk **105**. The direction of

5   the tangent to the grooves of the optical disk **105** is the direction in which the grooves are optically projected on the light detector **150**.

In the case where the non-point aberration method

10   is used for detecting a focusing error signal, when a non-point aberration is provided using a direction which is 45 degrees with respect to the grooves of the optical disk **105** as the axis, the direction in which the grooves are projected on the light detector **150** rotates by 90 degrees.

15   Accordingly, even when the actual division line is perpendicular to the tangent to the grooves of the optical disk **105**, such a division line is represented as being "parallel to the tangent to the grooves" in this specification, as long as such a division line is paral

20   to the tangent to the grooves projected on the light detector **150**.

The division line **302** passes through the center of the light which is projected on the light detector **150**

25   through the aperture of the objective lens **104** (Figure **1**). The division lines **301** and **303** are disposed so as to sandwich the overlapping area **200**. Distance d between the division lines **301** and **302** and distance d between the division lines **302** and **303** is each set to be equal to W/2. By such an

30   arrangement, as shown in Figure **2**, the overlapping area **200** of the plus first-order diffraction light and the minus first-order diffraction light obtained by the optical disk **105** is included within the detection areas **202, 203, 206**

and **207** of the light detector **150**. Signals which are obtained in accordance with the amount of light detected by the detection areas **201** through **208** are respectively indicated by s1 through s8.

A focusing error signal FE is obtained by expression (6).

$$FE=(s1+s2+s5+s6)-(s3+s4+s7+s8) \quad \ldots \quad (6)$$

In Figure **2**, an operation circuit for obtaining the focusing error signal FE is not shown.

Hereinafter, the information reproduction signal generator **450** for generating an RF signal, which is an information reproduction signal, will be described. The information reproduction signal generator **450** includes adders **401** through **405**. The RF signal is obtained based on the sum of the signals obtained from all the detection areas **201** through **208**. As shown in Figure 2, the adder **401** outputs the sum of "signal s1+signal s8", the adder **402** outputs the sum of "signal s2+signal s7", the adder **403** outputs the sum of "signal s3+signal s6", and the adder **404** outputs the sum of "signal s4+signal s5".

The adder **405** receives the outputs from the adders **401** through **404** and outputs the sum of the four outputs. The output from the adder **405**, which is the RF signal, can be represented by expression (7).

$$RF=s1+s2+s3+s4+s5+s6+s7+s8 \quad \ldots \quad (7)$$

Hereinafter, the tracking error signal generator **451** will be described. As shown in Figure 2, the tracking

error signal generator **451** includes the adders **401** and **404**, and a differential operation circuit **406**. The differential operation circuit **406** receives the outputs from the adders **401** and **404**, and outputs the difference between the two outputs. The output from the differential operation circuit **406**, i.e., a tracking error signal TE1, can be represented by expression (8).

$$TE1=(s1+s8)-(s4+s5) \dots (8)$$

The conventional optical head devices have the following drawbacks in tracking control when a tilt occurs (i.e., the optical disk **105** tilts with respect to the radial direction). The radial direction is the direction perpendicular to the tangent to the grooves of the optical disk **105**.

When the tilt occurs, the reflected light which is detected is offset in the direction of the tilt. When a tilt of the disk of θ occurs, the reflected light is offset by 2θ. For example, where the numerical aperture NA is 0.6, the angle θ of tilt is 0.8 degrees, and the aperture is a substantial circle having a radius of 1, $sin2\theta/NA=0.047$. The reflected light which is detected is offset by 0.047 in the direction of the tilt.

Where TE0 is a value of the tracking error signal which is obtained when the focal point F0 of the light from the objective lens **104** is at the center of the groove, TEmax is the maximum value of the tracking error signal which is obtained when the light has crossed the groove, and TEmin is the minimum value of the tracking error signal which is obtained when the light has crossed the groove; the

difference between |TEmax-TE0| (difference between the absolute values of TEmax and TE0) and |TEmin-TE0| (difference between the absolute values of TEmin and TE0) is increased.

5

Figure 3 is a graph illustrating the tracking error signal vs. off the track amount relationship. The off the track amount is the distance of the focal point F0 from the center of the track.

10

The curve having black squares represents the tracking error signal obtained when no aberration is provided. The solid line curve represents the tracking error signal obtained when a tilt occurs. The solid line

15 curve has the TEmax of 0.38, the TEmin of -0.42, and the TE0 of -0.20.

|TEmax-TE0|=0.58, and
|TEmin-TE0|=0.22.

20

The difference between |TEmax-TE0| and |TEmin-TE0| is significant.

When tracking control is performed in such a state,

25 the focal point F0 of the light from the objective lens **104** (Figure **1**) is off the center of the track, and thus information cannot be accurately recorded or reproduced.

In order to position the focal point F0 at the center

30 of the track, an offset voltage is applied to the tracking error signal as described below.

In Figure **3**, the curve having white triangles

represents the tracking error signal which is obtained by correcting the off-track amount to zero. An offset voltage is applied so that the center of the track matches the zero-cross point of the tracking error signal. At this point,

5   the upper amplitude of the tracking error signal from 0 level and the lower amplitude thereof from 0 are asymmetrical with each other.

When the upper amplitude and the lower amplitude

10   becomes excessively asymmetrical, the tracking control becomes unstable, which prevents accurate recording and reproduction of information.

As described above, in the conventional optical head

15   devices, when the difference between $|TEmax-TE0|$ and $|TEmin-TE0|$ becomes excessive, the off-track amount becomes excessively large. Even if an offset voltage is applied in order to reduce the off-track amount, the upper amplitude and the lower amplitude of the tracking error signal becomes

20   excessively asymmetric, as represented by the excessive degree of asymmetry of the upper and lower amplitudes which is obtained when the off-track amount is corrected to zero.

Comparison of the degrees of asymmetry of the

25   tracking error signal in the first example and a conventional optical head device will be described.

Where the numerical aperture NA of the objective lens 104 is 0.6, the wavelength λ of the light is 0.66 μm,

30   the distance Gp between the centers of two adjacent grooves of the optical disk 105 (Figure 1) is 1.48 μm, and the radius of the aperture is 1, the plus first-order diffraction light and the minus first-order diffraction light have an

overlapping area having a width W of 0.51.

The case where the thickness of the optical disk **105** is 0.6 mm and a tilt of 0.4 degrees occurs in the radial direction will be described.

In the conventional optical head device, the off-track amount is about 0.07 μm with respect to the center of the track. Application of an offset voltage so as to realize the off-track amount of zero, the upper and lower amplitudes of the tracking error signal is asymmetrical with each other by 31%.

The degree of asymmetry of the tracking error signal is defined by (A+B)/(A-B) where A is the maximum value of the upper amplitude of the tracking error signal and B is the minimum value of the lower amplitude thereof.

In the optical head device shown in Figure 2, the off-track amount of the light with respect to the center of the track can be restricted to as small as about 0.045 μm when the radial tilt of 0.4 degrees occurs, by obtaining the tracking error signal TE1 only from outside the overlapping area of the plus first-order diffraction light and the minus first-order diffraction light. The degree of asymmetry of the tracking error signal when the off-track amount is corrected to zero is 19%, which is 2/3 of the degree of asymmetry in the conventional optical head device.

In the conventional optical head device, when the object lens **104** shifts, the detection spot moves on the light detector **150**. When the off-track amount is corrected to zero, the degree of asymmetry of the upper and lower amplitudes

becomes excessive. For example, when the object lens **104** shifts by 150 μm, the degree of asymmetry is 16% when the off-track amount is corrected to zero.

5   In the optical head device shown in Figure **2**, when the object lens **104** shifts by 150 μm, the degree of asymmetry can be restricted as low as 3% when the off-track amount is corrected to zero.

10   As described above, in the optical head device shown in Figure **2**, even if the optical disk **105** tilts, stable tracking control can be performed while maintaining the off-track amount small. Thus, the optical head device shown in Figure **2** realizes recording and reproduction of 15   information with a sufficiently low error ratio.

          With reference to Figure **4**, another optical head device having an identical effect with that of the optical head device shown in Figure **2** will be described.
20
          Figure **4** shows a light detector **151** having detection areas **201**, **204**, **205**, **208** and **209**, an information reproduction signal generator **450**, and a tracking error signal generator **451** of the optical head device shown in 25   Figure **2**. The optical head device shown in Figure **4** is different from the optical head device shown in Figure **2** in that the light detector **151** is used instead of the light detector **150**. The arrangement of the optical system is identical as that of the optical head device shown in Figure 30   **2**.

          The light detector **151** is divided into detection areas **201, 204, 205, 208** and **209** by division lines **301, 303,**

305 and 306. The division lines 301 and 303 are disposed so as to sandwich an overlapping area of plus first-order diffraction light and minus first-order diffraction light, and the light corresponding to the overlapping area 200 is incident on the detection area 209 defined by the division lines 301 and 303.

The detection areas 201, 204, 205, 208 and 209 respectively generate signals s1, s2, s3, s4 and s5 in accordance with the amount of light received.

Hereinafter, the information reproduction signal generator 450 will be described. As shown in Figure 4, the information reproduction signal generator 450 includes adders 401, 404 and 405. An RF signal, which is an information reproduction signal, is obtained based on the sum of the signals obtained from all the detection areas 201, 204, 205, 208 and 209. As shown in Figure 4, the adder 401 outputs the sum of "signal s1+signal s4", and the adder 404 outputs the sum of "signal s2+signal s3". The adder 405 receives the outputs from the adders 401 and 404 and the signal s5 from the detection area 209, and outputs the sum of the three outputs. The output from the adder 405, which is the RF signal, can be represented by expression (9).

$$RF = s1 + s2 + s3 + s4 + s5 \quad \ldots \quad (9)$$

Hereinafter, the tracking error signal generator 451 will be described. As shown in Figure 4, the tracking error signal generator 451 includes the adders 401 and 404, and a differential operation circuit 406. The differential operation circuit 406 receives the outputs from the adders 401 and 404, and outputs the difference between the two

outputs.   The output from the differential operation circuit **406**, i.e., a tracking error signal TE1, can be represented by expression (10).

5          $TE1=(s1+s4)-(s2+s3) \quad ... \quad (10)$

In the optical head device shown in Figure **4**, the identical effect as that of the optical head device shown in Figure **2** can be obtained with a smaller number of detection
10   areas and head amplifiers.

With reference to Figure **5**, still another optical head device having the identical effect with that of the optical head device shown in Figure **2** will be described.
15

Figure **5** shows a light detector **152** having eight detection areas defined by division lines **306** through **309**. The division lines **307** and **309** which are perpendicular to the tangent to the grooves of the optical disk are disposed
20   so as to sandwich an overlapping area **200** of plus first-order diffraction light and minus first-order diffraction light. Detection areas **210** through **213** which are outside the division lines **307** and **309** and do not include the center of the aperture respectively generate signals s1, s2, s3,
25   and s4 in accordance with the amount of light received.

The tracking error signal TE1 can be obtained by expression (11).

30          $TE1=(s1+s4)-(s2+s3) \quad ... \quad (11)$

In such a structure, the diffraction light can be received except for the major part of the overlapping area

200 of the plus first-order diffraction light and the minus first-order diffraction light. Accordingly, the characteristics of the tracking error signal can be improved as satisfactorily as the optical head devices shown in Figures **2** and **4**. Thus, the optical head device partially shown in Figure **5** performs stable tracking control with a relatively small off-track amount, and thus realizes recording and reproduction of information with a sufficiently low error ratio.

With reference to Figure **6**, still another optical head device having the identical effect with that of the optical head device shown in Figure **2** will be described.

Figure **6** shows a light detector **153** having eight detection areas defined by division lines **310** through **313**. The division lines **310** and **312** which are parallel to the tangent to the grooves of the optical disk are disposed near the periphery of the cross section of the light **108a** (Figure **1**) on the light detector **153**. Detection areas **214** through **217** which are outside the division lines **310** and **312** and do not include the center of the circle **A** respectively generate signals s1, s2, s3, and s4 in accordance with the amount of light received.

The tracking error signal TE1 can also be obtained by expression (11).

In such a structure, the diffraction light can be received from the areas sufficiently far from the over-lapping area **200** of the plus first-order diffraction light and the minus first-order diffraction light. Accordingly, the characteristics of the tracking error signal can be

improved as satisfactorily as the optical head devices shown in Figures 2 and 4. Thus, the optical head device partially shown in Figure 6 performs stable tracking control with a relatively small off-track amount, and thus realizes recording and reproduction of information with a sufficiently low error ratio.

In Figures 2, 4, 5 and 6, the division lines are straight. Since the overlapping area 200 of the plus first-order diffraction light and the minus first-order diffraction light is enclosed by a curve, the division lines may be curved lines in accordance with the overlapping area 200.

(Example 2)

In a second example according to the present invention, a tracking error signal is corrected based on a signal obtained from the overlapping area of the plus first-order diffraction light and the minus first-order diffraction light which are obtained by the grooves of the optical disk 105 (Figure 1). In the second example also, the conditions represented by expression (4) described above are fulfilled.

The structure and operation of an optical head device in the second example are substantially the same as those of the optical system shown in Figure 1, and thus detailed description thereof will be omitted.

Figure 7 shows a light detector 150 including detection areas 201 through 208, and a tracking error signal generator 451 of an optical head device according to the second example of the present invention.

The light detector 150 is divided into the eight detection areas 201 through 208 by division lines 301 through 304. The division lines are disposed in the same manner as
5   shown in Figure 2. The detection areas 201 through 208 respectively generate signals s1 through s8 in accordance with the amount of light received. The method for generating the focusing error signal FE and the information reproduction signal are the same as described in the first
10   example with reference to Figure 2 and will not be described in the second example.

As shown in Figure 7, the tracking error signal generator 451 includes adders 401 through 404, 407 and 408,
15   and a differential operation circuit 406. As shown in Figure 7, the adder 401 outputs the sum of "signal s1+signal s8", the adder 402 outputs the sum of "signal s2+signal s7", the adder 403 outputs the sum of "signal s3+signal s6", and the adder 404 outputs the sum of "signal s4+signal s5". The
20   adder 407 receives the outputs from the adders 401 and 403 and outputs the sum of the two outputs. The adder 408 receives the outputs from the adders 402 and 404 and outputs the sum of the two outputs. The differential operation circuit 406 receives the outputs from the adders 407 and
25   408, and outputs the difference between the two outputs.

The output from the differential operation circuit 406, i.e., a tracking error signal, can be represented by expression (12).
30

TE1=(s1+s3+s6+s8)-(s2+s4+s5+s7) ... (12)

The method of processing a signal generated by the

detection areas which receive the light corresponding to the overlapping area **200** of the plus first-order diffraction light and the minus first-order diffraction light, which is carried out by the structure of Figure **7**, is different

5   from the usual push-pull method.   In the structure of Figure **7**, the tracking error signal is corrected by inverting at least one of the signals generated by the detection areas which receive the light corresponding to the overlapping area **200** and then adding together the inverted signal and

10   the other signals.

In the optical head device shown in Figure **7**, when a tilt of 0.4 degrees occurs in the radial direction, the degree of asymmetry of the upper and lower amplitudes of

15   the signal with respect to zero is 14% even when the off-track amount is corrected to zero. This degree of asymmetry is about 1/2 of the degree obtained in the conventional optical head device. The structure and method for correcting the tracking error signal described with reference to Figure

20   **7** is specifically advantageous for restricting the asymmetry against a radial tilt.

As described above, the optical head device shown in Figure **7** performs stable tracking control with a

25   relatively small off-track amount even if a tilt of the optical disk **105** (Figure **1**) occurs, and thus realizes recording and reproduction of information with a sufficiently low error ratio.

30   With reference to Figure **8**, another optical head device having the identical effect with that of the optical head device shown in Figure **7** will be described.

Figure **8** shows a light detector **153** including 12 detection areas **218** through **229** defined by division lines **315** through **320**, and a tracking error signal generator **451**.

5　　　　The division lines **315** and **319** are parallel to the tangent to the grooves of the optical disk **105** (Figure **1**) and disposed so as to interpose an overlapping area **200** of the plus first-order diffraction light and the minus first-order diffraction light obtained by the grooves of 10　　　the optical disk **105**. The distance between the division lines **315** and **319** is approximately the same as W in expression (5) described above with reference to Figure **2**. The division lines **316** through **318** are disposed equally spaced between the division lines **315** and **319**. The detection areas **218** 15　　　through **229** respectively generate signals s1 through s12 in accordance with the amount of light received.

As shown in Figure **8**, the tracking error signal generator **451** includes adders **401** through **404** and **409** through 20　　　**412**, and a differential operation circuit **406**.

As shown in Figure **8**, the adder **401** outputs the sum of "signal s1+signal s12", the adder **402** outputs the sum of "signal s2+signal s11", the adder **403** outputs the sum 25　　　of "signal s3+signal s10", the adder **404** outputs the sum of "signal s4+signal s9", the adder **409** outputs the sum of "signal s5+signal s8", and the adder **410** outputs the sum of "signal s6+signal s7". The adder **411** receives the outputs from the adders **401**, **403**, and **409** and outputs the sum of 30　　　the three outputs. The adder **412** receives the outputs from the adders **402**, **404** and **410** and outputs the sum of the three outputs. The differential operation circuit **406** receives the outputs from the adders **411** and **412**, and outputs the

difference between the two outputs.

The output from the differential operation circuit
406, i.e., a tracking error signal, can be represented by
expression (13).

$$TE1=(s1+s3+s5+s8+s10+s12)-(s2+s4+s6+s7+s9+11)$$
$$...(13)$$

In the optical head device shown in Figure **8**, even
when a tilt of 0.4 degrees occurs in the radial direction,
the off-track amount is merely 0.042 μm.

When the off-track amount is corrected to zero, the
degree of asymmetry of the upper and lower amplitudes of
the tracking error signal with respect to zero is 18%,
whereas the degree of asymmetry in the conventional optical
head device is 31%. As can be understood from this, the
optical head device shown in Figure **8** provides a smaller
degree of asymmetry than in the conventional optical head
device even when the off-track amount is corrected to zero.

When the objective lens shifts by 150 μm, the degree
of asymmetry in the optical head device shown in Figure **8**
is 8% when the off-track amount is corrected to zero, whereas
the degree of asymmetry in the conventional optical head
device is 16%. As is apparent from this, the optical head
device shown in Figure **8** reduces the asymmetry of the
tracking error signal to about half compared to the
conventional optical head device.

As described above, the optical head device shown
in Figure **8** performs stable tracking control with a

relatively small off-track amount even if a tilt of the optical disk **105** occurs, and thus realizes recording and reproduction of information with a sufficiently low error ratio.

5

In the second example, the overlapping area **200** of the plus first-order diffraction light and the minus first-order diffraction light is divided into four in the direction perpendicular to the tangent to the grooves of
10 the optical disk **105**. The overlapping area **200** may be divided into a greater number of areas, in which case, the same effect can be obtained.

The division line **320** which is perpendicular to the
15 tangent to the grooves of the optical disk is provided in consideration of the non-point aberration method used for focusing the light. In the case where the division line **320** is not provided, the adders **401** through **404**, **409** and **410** are not necessary. In such a case, the same effect can be
20 obtained.

(Example 3)
In a third example according to the present invention, a tracking error signal is corrected by
25 generating a correction signal corresponding to disturbance from a signal obtained from the overlapping area of the plus first-order diffraction light and the minus first-order diffraction light which are obtained by the grooves of the optical disk **105** (Figure 1). In the third example also, the
30 conditions represented by expression (4) described above are fulfilled.

The structure and operation of an optical head

device in the third example are substantially the same as those of the optical system shown in Figure 1, and thus detailed description thereof will be omitted.

5   Figure 9 shows a light detector 150 including detection areas 201 through 208, and a tracking error signal generator 451 of an optical head device according to the third example of the present invention.

10   The light detector 150 is divided into the eight detection areas 201 through 208 by division lines 301 through 304. The division lines are disposed in the same manner as shown in Figure 2. The detection areas 201 through 208 respectively generate signals s1 through s8 in accordance
15 with the amount of light received.

      The method for generating the focusing error signal FE and the information reproduction signal are the same as described in the first example with reference to Figure 2
20 and will not be described in the third example.

      As shown in Figure 9, the tracking error signal generator 451 includes adders 401 through 404, variable gain amplification circuits 413 and 414, and differential
25 operation circuits 406, 415 and 416.

      The variable gain amplification circuit 414 receives an output from the adder 402 and outputs a signal obtained by multiplying the output from the adder 402 by
30 α1, (α1 being a prescribed value). The variable gain amplification circuit 413 receives an output from the adder 403 and outputs a signal obtained by multiplying the output from the adder 403 by α2, (α2 being a prescribed value).

The differential operation circuit **406** receives outputs from the adders **401** and **404** and outputs a signal obtained by subtracting the output of the adder **404** from the output of the adder **401**.

The differential operation circuit **415** receives the outputs from the variable gain amplification circuits **413** and **414**, and outputs their difference.

The differential operation circuit **416** receives the outputs from their differential operation circuits **406** and **415**, and outputs their difference.

The output from the differential operation circuit **416** (i.e., a tracking error signal) can be represented by expression (14).

$$TE1=(s1+s8)-(s4+s5)-\{\alpha a1 (s2+s7)-\alpha 2 \cdot (s3+s6)\} \dots (14)$$

The gain $\alpha 1$ of the variable gain amplification circuit **414** and gain $\alpha 2$ of the variable gain amplification circuit **413** are determined in consideration of the amount and polarity of the radial tilt and the amount and polarity of the shift of the objective lens. By changing the gains $\alpha 1$ and $\alpha 2$, the difference between $|TEmax-TE0|$ and $|TEmin-TE0|$ can be reduced. In other words, the correction amount can be reduced by adjusting the gains. The optical head device shown in Figure **9** according to the third example is more advantageous over the optical head devices of the second example with respect to improving the amount of correction.

As described above, the optical head device shown in Figure **9** provides stable tracking control with relatively small off-track error even if a tilt of the optical disk **105** (Figure **1**) occurs, and thus realizes recording and reproduction of information with a substantially low error ratio.

In the third example, the overlapping area **200** of the plus first-order diffraction light and the minus first-order diffraction light is divided into two in the direction perpendicular to the tangent to the grooves of the optical disk **105**. The overlapping area **200** may be divided into a greater number of areas, in which case, the same effect can be obtained.

(Example 4)

In a fourth example according to the present invention, characteristics of a tracking error signal are improved by reducing the optical transmission of an area including an overlapping area of the plus first-order diffraction light and the minus first-order diffraction light which are obtained by the grooves of the optical disk **105** (Figure **10A**). In the fourth example, the conditions represented by expression (4) described above also are fulfilled.

Figure **10A** is a schematic view of an optical system of an optical head device according to the fourth example of the present invention. The optical system in Figure **10A** is identical with that of the optical system shown in Figure **1** except with respect to the objective lens **109**. Accordingly, a detailed description of the optical system except for the objective lens **109** will be omitted.

Figure **10B** is a front view of the objective lens **109** which is included in the collection optical system of the optical head device shown in Figure **10A**. A holographic element is provided on the objective lens **109** in a hatched area **110** as a light reducing element. The light diffracted by the holographic element becomes unnecessary light, which does not contribute to the reproduction of the signal. Only zero-the order light which is not diffracted by the holographic element is effectively collected on the information layer **108** of the optical disk **105**.

Detection areas **251** through **254** of a light detector **150** can be arranged as shown in Figure **43A**. In the case where the detection areas **251** through **254** are arranged as shown in Figure **43A**, a tracking error signal TE1, a focusing error signal FE, and an information reproduction signal RF are obtained by the expressions (1), (2) and (3), respectively.

Comparison of the degrees of asymmetry of the tracking error signal in the fourth example and a conventional optical head device will be described.

The comparison is performed by correcting the off-track amount to zero under the same conditions as those described regarding the optical head device shown in Figure 2, in the case where the transmittance T of the area **110** is 55%, the ratio of the radius of the area **110** with respect to the radius of the objective lens **109** is 0.72, and the angle of the radial tilt is 0.4 degrees. The degree of asymmetry of the upper and lower amplitudes of the tracking error signal is restricted to 17% in the optical head device shown in Figure **10A**, whereas the degree of asymmetry is 31%

in the conventional optical head device. The degree of asymmetry obtained in the optical head device shown in Figure 10A is about 1/2 of the degree obtained in the conventional optical head device.

5

As described above, in the optical head device shown in Figure 10A, even if the optical disk **105** tilts, stable tracking control can be performed while maintaining the off-track amount small. Thus, the optical head device shown in Figure **10A** realizes recording and reproduction of information with a sufficiently low error ratio.

10

In this example, another light spot may be formed by light diffracted by the holographic element provided on the objective lens **109**. In such a case, zero-the order diffraction light can be used to form a spot for a DVD having a thickness of 0.6 mm, and first-order diffraction light can be used to form a spot for a CD having a thickness of 1.2 mm thick. By forming a different light spot by light diffracted on the holographic element, the function of a bifocal lens can be provided.

15

20

In this example, the holographic element is provided as a light reducing element. The same effect can be obtained by providing the objective lens with a reflection film having an appropriate transmittance or providing the objective lens with a light absorption film.

25

Alternatively, as shown in Figure 11, a holographic element or filter **111** including a light reducing film may be held so as not to be moved with respect to the objective lens **104**, in lieu of directly attaching any of the above-mentioned light reducing elements on the objective

30

lens. In such a case, the same effect can be obtained.

In Figure 11, the filter 111 as a light reducing element covers a surface of the objective lens 104 which is farther from the optical disk 105, but may cover a surface of the object lens 104 which is closer to the optical disk 105. Similarly, the light reducing element in Figure 10A can cover a surface of the objective lens 10 which is closer to the optical disk 105.

In the fourth example, the light reducing element is provided integrally with the collection optical system, but may be provided in the fixed optical system separately from the collection optical system. Figure 12 shows an exemplary optical head device including a light reducing element on a light path from the light source to the optical disk. As shown in Figure 12, the light emitted by the semiconductor laser 101 as a light source passes through a filter 111 as a light reducing element. By the filter 111, the light corresponding to a central area of the filter 111 is reduced. The remaining light is reflected by the plane-parallel beam splitter 102. In such a structure, the zero-the order diffraction light in the overlapping area of the plus first-order diffraction light and the minus first-order diffraction light which are obtained from the grooves of the optical disk 105 is reduced. Thus, the influence of the overlapping area can be reduced.

Figure 13 shows an exemplary optical head device including a light reducing element in an optical system from the optical disk to the light detector 150. In Figure 13, a light reducing element 113 is provided on a bottom surface of a plane-parallel beam splitter 112. In such an

arrangement also, the influence of the overlapping area of the plus first-order diffraction light and the minus first-order diffraction light can be reduced, and the same effect can be obtained.

5

In the first through fourth examples, the non-point aberration method is used for obtaining a focusing error signal. The present invention is not limited to such a method. The non-point aberration method can be used in

10   combination with other methods such as the Foucault method or the spot size method.

(Example 5)
In a fifth example according to the present

15   invention, a holographic element or a stepped prism is used as a light division element. A focusing error signal is obtained by the spot size method. In the fifth example also, the conditions represented by expression (4) described above are fulfilled.

20

An optical head device according to the fifth example of the present invention will be described with reference to Figure 14. Figure 14 is a schematic view of an optical system of the optical head device. The optical

25   head device shown in Figure 14 operates in the following manner.

Light emitted by a semiconductor laser 101 (used as a light source) is collimated by a collimator lens 103 and

30   then reflected by a beam splitter 115. Then, the light is converged by an objective lens 104, which is a part of the optical system, and then collected on an information layer 108 of an optical disk 105 employed as an information memory

medium.   The light is then reflected by the information layer **108** of the optical disk **105** as light **108a**, which is transmitted back through the objective lens **104** to be collimated.   The collimated light **108a** is then transmitted

5   through the beam splitter **115** and converged by a detection lens **116**.   The converged light **108a** is diffracted by a holographic element **117** provided as a light division element. Minus first-order diffraction light **108b** and plus first-order diffraction light **108c** obtained by the

10   diffraction performed by the holographic element **117** are received by a light detector **154**.

Figure **15** shows a pattern for dividing the holographic element **117**, a detection area of the light

15   detector **154**, and cross sections of the minus first-order diffraction light **108b** and the plus first-order diffraction light **108c** on the light detector **154**.

The holographic element **117** is divided into a

20   plurality of strip-shaped areas **A, a, B, b, C, c, D** and **d**. These letters indicating the strip-shaped areas also indicate the corresponding cross sections of the minus first-order diffraction light **108b** and the plus first-order diffraction light **108c**.   The minus first-order diffraction

25   light **108b** obtained from the areas represented by capital letters **A, B, C** and **D** is collected farther from the minus first-order diffraction light **108b** obtained from the areas represented by lower case letters **a, b, c** and **d** with respect to the detection lens **116**.

30

The optical system and the holographic element **117** are designed so that, when the focal point F0 of the light from the objective lens **104** matches the information layer

108 of the optical disk 105, the cross section of the diffraction light obtained from the areas represented by the capital letters **A, B, C** and **D** has an equal size to that of the cross section of the diffraction light obtained from the areas represented by the lower case letters **a, b, c** and **d**.

Detection areas **230, 231** and **232** of the light detector **154** generates signals f1, f2 and f3 in accordance with the amount of light received.

A focus error signal FE is obtained by expression (15).

$$FE=f1+f3-f2 \ ... \ (15)$$

When the information layer **108** is distanced from the objective lens **104** to be beyond the focal point F0 of the light from the objective lens **104**, the cross sections **A, B, C** and **D** of the minus first-order diffraction light **108b** are decreased, and the cross sections **a, b, c** and **d** of the minus first-order diffraction light **108b** are increased. Accordingly, the amplitudes of signals f1 and f3 reduce and the amplitude of signal f2 increases. The amplitude of the focusing error signal FE reduces.

When the information layer **108** approaches the objective lens **104** to be between the objective lens **104** and the focal point F0 of the light from the objective lens **104**, the cross sections **A, B, C** and **D** of the minus first-order diffraction light **108b** are increased, and the cross sections **a, b, c** and **d** of the minus first-order diffraction light **108b** are decreased. Accordingly, the amplitudes of signals f1 and f3 increase and the amplitude of signal f2 reduces.

The amplitude of the focusing error signal FE increases.

In such a system, focusing control for maintaining the focal point F0 on the information layer **108** is realized.

Detection areas **233** through **236** of the light detector **154** generate signals t1 through t4 in accordance with the mount of light received. An operation circuit (not shown) generates a tracking error signal TE1.

The tracking error signal TE1 is obtained by expression (16).

$$TE1=(t1+t4)-(t2+t3) \ldots (16)$$

This substantially provides the difference in light amount between the hatched areas and the blank areas in Figure **15**.

By the differential phase method, a tracking error signal TE2 is obtained by comparing the phase of (signal t1+signal t3) and the phase of (signal t2+signal t4).

An RF signal for reproducing the information is obtained as RFf by expression (17), as RFt by expression (18), or as the sum of RFf and RFt.

$$RFf=f1+f2+f3 \ldots (17)$$

$$RFt=t1+t2+t3+t4 \ldots (18)$$

A feature of the optical head device shown in Figure **15** is that a plurality of areas sandwiching the division

line (which runs through the center of the aperture and is parallel to the grooves of the optical disk) are exchanged with each other diagonally. In Figure 15, the total of eight areas, namely, areas **A** and **D**, areas **B** and **C**, areas **a** and

5   **d**, and areas **b** and **c** are exchanged with each other. Thus, the same effect as that of the second example can be obtained. In more detail, when a tilt of 0.4 degrees occurs in a radial direction, the degree of asymmetry of the upper and lower amplitudes of the tracking error signal is 14% when the

10   off-track amount is corrected to zero. The degree of 14% is about 1/2 of the degree of asymmetry obtained in the conventional optical head device. The optical head device shown in Figure **15** is specifically advantageous for restricting a radial tilt.

15

As described above, in the optical head device shown in Figure **15**, even if the optical disk **105** (Figure **14**) tilts, stable tracking control can be performed while maintaining the off-track amount small. Thus, the optical head device

20   shown in Figure **15** realizes recording and reproduction of information with a substantially low error ratio.

Figure **16** shows another pattern for dividing a holographic element **118**. In Figure **16**, only a part of the

25   areas sandwiching the division line (which runs through the center of the aperture and is parallel to the grooves of the optical disk) are exchanged with each other diagonally. In this case, the same effect as that described in the second example with reference to Figure **8** can be obtained. In the

30   case where the angle of the radial tilt is 0.4 degrees, the off-track amount is 0.042 μm. When the off-track amount is corrected to zero, the degree of asymmetry of the upper and lower amplitudes of the tracking error signal is 18%. In

the conventional optical head device, in the case where the angle of the radial tilt is 0.4 degrees, the degree of asymmetry is 31% when the off-track amount is corrected to zero. The optical head device shown in Figure **16** using the
5   holographic element **118** significantly reduces the degree of asymmetry of the tracking error signal compared to the conventional optical head device.

In the optical head device shown in Figure **16** using
10   the holographic element **118**, in the case where the objective lens shifts by 150 μm, the degree of asymmetry of the upper and lower amplitudes of the tracking error signal is 8% when the off-track amount is corrected to zero. In the conventional optical head device, in the case where the
15   objective lens shifts by 150 μm, the degree of asymmetry is 16% when the off-track amount is corrected to zero. The optical head device shown in Figure **16** using the holographic element **118** significantly reduces the degree of asymmetry of the tracking error signal compared to conventional
20   optical head devices.

As described above, in the optical head device shown in Figure **16**, even if the optical disk **105** (Figure **14**) tilts, stable tracking control can be performed while maintaining
25   the off-track error small. Thus, the optical head device shown in Figure **16** realizes recording and reproduction of information with a substantially low error ratio.

As can be understood from the above description,
30   according to the optical head device in the fifth example, a significant effect can be achieved by using a holographic element as a light division element, without increasing the number of detection areas of the light detector compared

to conventional devices. Such a structure does not require the number of head amplifiers for generating an RF signal to be increased, and thus the circuit can be simplified.

5   In the fifth example, the aperture is divided by a division line which is perpendicular to the tangent to the tracks. Areas **a** through **d** and areas **A** through **D** are arranged to sandwich the division line. The areas **a** through **d** form a spherical wave having a light collection point on the side

10   closer to the collimator lens **103**; and areas **A** through **D** form a spherical wave having a light collection point on the side farther from the collimator lens **103**. In addition, these two types of areas are arranged alternately in an area outside the aperture which is not usually irradiated by

15   light.

    In the case where the division line perpendicular to the tracks is not provided and strip-like areas extending parallel to the tracks from one end to the other end of the

20   aperture are provided, when the holographic element **117** is offset with respect to the center of the aperture of the objective lens **104**, the balance between the amount of light incident on the areas **a** through **d** of the light detector **154** and the amount of light incident on the areas **A** through **D**

25   is spoiled. When the light collection point F0 of the light from the objective lens **104** is off the information layer **108** of the optical disk **105** to cause defocus, stripes of bright areas and dark areas which are parallel to the tracks are formed in an area where the ±first-order diffraction

30   light formed by the optical disk **105** and the zero-th order light overlap. Again, the balance between the amount of light incident on the areas **a** through **d** of the light detector **154** and the amount of light incident on the areas **A** through

D is spoiled by the manner in which the stripes and the areas of the holographic element **117** overlap.

On calculation, in a conventional device where there is no division line perpendicular to the tangent to the tracks, under the conditions where the numerical aperture NA of the objective lens is 0.5, the wavelength λ of light is 0.795 μm, the diameter of the objective lens is 4 mm, the width of each area of the holographic element is 0.2 mm, and the objective lens is off with respect to the center of the polarization anisotropic holographic element by 100 μm, the focus gain changes by 3.4 dB by the defocus of ± 2 μm.

In the case of the arrangement according to the fifth example, the focus gain changes only by 1.2 dB under the same conditions on calculation. Such a change is about 1/3 of the conventional device, indicating a significant reduction. Thus, the focus control is stabilized against disturbance. Accordingly, the error ratio in information reproduction is reduced.

In the case where the above-described two types of areas are provided outside the aperture without any division line perpendicular to the tracks, the focus gain changes only by 1.8 dB under the same conditions on calculation. Such a change is about 1/2 of the conventional device. Accordingly, the focus control is stabilized, and thus the error ratio in information reproduction is reduced.

The pattern for dividing the holographic element can be set more freely than the pattern for dividing the light detector. Accordingly, a suitable pattern for a particular

purpose can be easily realized.

In the fifth example, only a holographic element is used. Alternatively, a polarizing anisotropic holographic element can be used in combination with a 1/4-wave plate. In this case, the light utilization factor can be improved without spoiling the above-described effect of the present invention.

In the fifth example, a light division element for performing both the focusing control and the tracking control is provided. Since the focusing control and the tracking control are independent from each other, a light division element for performing either one of them may be provided. In such a case, the effect in accordance with such a structure can be obtained.

In lieu of a holographic element, a stepped prism may be used as the light division element. Figure 17 is a schematic view of an optical system including a stepped prism 119 in place of the holographic element 117 shown in Figure 14. The light divided by the stepped prism 119 is received by the light detector 154. In this case also, the same effect as in the structure using a holographic element can be obtained.

(Example 6)
In a sixth example according to the present invention, a structure and method for reproducing information which is recorded at a position off the grooves of the optical disk used as an information memory medium will be described.

An optical system of the optical head device used in the sixth example has substantially the same structure as and operates in the same manner as the optical system shown in Figure 1, and thus will not described in detail.

Figure **18** shows detection areas of the light detector **150**, an information reproduction signal generator **450** and a tracking error signal generator **451** of the optical head device.

The light detector **150** is divided into eight detection areas **201** through **208** by division lines **301** through **304**. The division lines **301** through **304** are disposed in the same manner as in Figure **2**. The detection areas **201** through **208** generate signals s1 through s8 in accordance with the amount of light received.

As shown in Figure **18**, the information reproduction signal generator **450** includes adders **401** through **404** and **405**, **417** and **419**, and differential operation circuits **418** and **420**. The tracking error signal generator **451** includes the adders **401** through **404**, **421** and **422**, and a differential operation circuit **423**. The optical head device shown in Figure **18** further includes an address detection circuit **424** and a control circuit **425**.

With reference to Figures **19A**, **19B** and **19C**, the operation for reading a series of pits recorded off the grooves in the optical disk will be described.

Figure **19A** shows a part of the optical disk having a groove **501** and a series of pits **502** on the information layer **108** (Figure **1**).

A track **507** runs along the center of the grooves **501** in zones **503** and **506**. In a first address zone **504**, a center line **508** of the series of pits is off the track **507** in one direction by a prescribed distance. In a second address zone **505**, a center line **509** of the series of pits is off the track **507** in the opposite direction by a prescribed distance.

When the focal point F0 of the light from the objective lens **104** (Figure **1**) is in the zone **503** or **506**, the focal point F0 is on the track **507**, for example, on a point **510** in the case where tracking control is performed. While the optical disk **105** (Figure **1**) rotates and thus moves with respect to the optical head device, the focal point F0 moves from the point **510** to a point **511**, a point **512**, and a point **513** on an extension of the track **507**. While the focal point F0 is in the first address zone **504** and the second address zone **505**, the tracking error signal is on hold.

A focusing error signal FE is obtained as in the first example based on expression (6).

$$FE=(s1+s2+s5+s6)-(s3+s4+s7+s8) \ldots (6)$$

The tracking error signal THE is generated by the tracking error signal generator **451** in the following manner.

The adder **421** receives signal t1 from the adder **401** and signal t2 from the adder **402**, and outputs the sum of signals t1 and t2. The adder **422** receives signal t3 from the adder **403** and signal t4 from the adder **404**, and outputs the sum of signals t3 and t4. The differential operation circuit **423** receives the signals from the adders **421** and

422, and outputs the difference between the two signals. The output from the differential operation circuit **423**, (i.e., the tracking signal THE) is obtained based on expression (19).

$$THE=(t1+t2)-(t3+t4) \ldots (19)$$

The tracking control is performed by the tracking error signal THE.

The information reproduction signal generator **450** generates an information reproduction signal RF in the following manner.

The adder **401** receives signals s1 and s8, and outputs signal t1, which is the sum of signals s1 and s8. The adder **402** receives signals s2 and s7, and outputs signal t2, which is the sum of signals s2 and s7. The adder **403** receives signals s3 and s6, and outputs signal t3, which is the sum of signals s3 and s6. The adder **404** receives signals s4 and s5, and outputs signal t4, which is the sum of signals s4 and s5. The adder **405** receives signals t1 through t4 from the adders **401** through **404**, and outputs the sum of the four signals. The output from the adder **405**, which is an information reproduction signal RF, is obtained by expression (20).

$$RF=t1+t2+t3+t4 \ldots (20)$$

The adder **417** receives signals t2, t3 and t4 from the adders **402**, **403** and **404**, and outputs the sum of the three signals. The differential operation circuit **418** receives the signals from the adders **401** and **417**, and outputs the

difference between the two signals. The output from the differential operation circuit **418**, (i.e., signal RFa1) is obtained by expression (21).

5
$$RFa1=t1-(t2+t3+t4) \ldots (21)$$

The adder **419** receives signals t1, t2 and t3 from the adders **401**, **402** and **403**, and outputs the sum of the three signals. The differential operation circuit **420** receives
10 the signals from the adders **419** and **404**, and outputs the difference between the two signals. The output from the differential operation circuit **420**, (i.e., signal RFa2) is obtained by expression (22).

15
$$Rfa2=(t1+t2+t3)-t4 \ldots (22)$$

The address detection circuit **424** receives the tracking error signal THE from the differential operation circuit **423**. Then, the address detection circuit **424**
20 determines whether the focal point F0 of the light from the objective lens is in the zone **503** or **506** having the groove **501**, in the first address zone **504** or the second address zone **505**, and outputs an identification signal indicating the determination result.
25
The control circuit **425** receives the identification signal from the address detection circuit **424**, and controls switches **426** and **427** based on the identification signal.

30
The switch **426** receives the signals from the differential operation circuits **418** and **420**, and outputs one of the two signals.

The switch **427** receives the signals from the adder **405** and the switch **426**, and outputs one of the two signals. The signal output from the switch **427** is used for reproducing the information or address stored in the optical disk **105**
5   (Figure **1**).

The control circuit **425** controls the switches **426** and **427** so that, when the focal point F0 of the light from the objective lens is in the zone **503** or **506** having the groove
10   **501**, the switch **427** outputs the signal RF which is input from the adder **405**. The control circuit **425** also controls the switches **426** and **427** so that, when the focal point F0 is in the first address zone **504**, the switch **427** outputs the signal RFa1 which is input from the differential
15   operation circuit **418**; and so that, when the focal point F0 is in the second address zone **505**, the switch **427** outputs the signal RFa2 which is input from the differential operation circuit **420**.

20   Through the above-described control of the control circuit **425**, information stored in the optical disk is reproduced in the following manner.

When the focal point F0 is at the point **511** in the
25   first address zone **504**, information stored in the series of pits corresponding to the track **507** is reproduced based on signal RFa1, which indicates the difference between the signals obtained from the two areas (lined area and hatched area) sandwiching the division line **301**.
30

When the focal point F0 is at the point **512** in the second address zone **505**, information stored in the series of pits corresponding to the track **507** is reproduced based

on signal RFa2, which indicates the difference between the signals obtained from the two areas (lined area and hatched area) sandwiching the division line **303**.

Hereinafter, comparison between the optical head device shown in Figure **18** and the conventional optical head device regarding the jitter will be described. In the following comparison, the numerical aperture NA of the objective lens is 0.6, the wavelength λ of the light is 0.660 μm, and the space Gp between two adjacent guiding grooves is 1.48 μm. The center line **508** of the series of pits **502** in the first address zone **504** and the center line **509** of the series of pits **502** in the second address zone **505** are each off the center line of the track **507** by 0.37 μm.

In the conventional optical head device, in which the information is reproduced based on a signal indicating the difference among the signals obtained from each of the areas in the light detector defined by a central division line of the aperture, the jitter obtained by calculation is 6.4%.

In the optical head device shown in Figure **18**, the information can be reproduced in the following manner. The division line **302** divides the aperture equally into two. The aperture has a radius of 1. The distance between the division lines **301** and **302** is represented by d, and the distance between the division lines **303** and **302** is also represented by d, where d=0.23. The aperture is divided into two detection areas by the division line **301** or **303**, and the information is reproduced based on a signal indicating the difference between the signals obtained from the two detection areas, namely, signals RFa1 or RFa2. In such a

system, the jitter obtained by calculation is 1.8%. Thus, the optical head device shown in Figure **18** can improve the jitter by 4% or more compared to the conventional optical head device.

In the case where d is 0.1 or more and 0.3 or less, the jitter is 3% or less in the optical head device shown in Figure **18**. In this case, such a level of jitter is half or less of the jitter obtained in the conventional optical head device.

Figure **50** shows the result of the calculation of the jitter. The horizontal axis represents the distance from the division line **302** passing through the aperture having a radius of 1. The distance toward the division line **303** is represented by positive values, and the distance toward the division line **301** is represented by negative values. The vertical axis represents the calculated jitter. White squares indicate the values when the focal length FO is in the first address zone **504** as shown in Figure **19A**, and black squares indicate the values when the focal length FO is in the second address zone **505** as shown in Figure **19A**. It can be appreciated from Figure **50** that the jitter is reduced by shifting the division line to the negative side (toward the division line **301**) when reproducing the information in the first address zone **504** and by shifting the division line to the positive side (toward the division line **303**) when reproducing the information in the second address zone **505**.

As described above, in the optical head device shown in Figure **18**, information stored in the form of a series of pits which are positioned off the track can be reproduced with a sufficiently low level of jitter. Accordingly, a

margin against disturbance and the like is increased, and thus information such as addresses can be recorded to and reproduced from the optical disk in the form of pits with satisfactory stability.

5

With reference to Figure 20, an optical head device having a different light detector 151 from the detector shown in Figure 18 will be described.

10   Figure 20 shows detection areas 201, 204, 205, 208 and 209 of the light detector 151, an information reproduction signal generator 450 and a tracking error signal generator 451 of the optical head device.

15   As shown in Figure 20, the information reproduction signal generator 450 includes adders 401, 404, 405, 417 and 419 and differential operation circuits 418 and 420. The tracking error signal generator 451 includes the adders 401 and 404, and a differential operation circuit 423. The
20   optical head device shown in Figure 20 further includes an address detection circuit 424 and a control circuit 425.

The adder 405 generates a signal corresponding to the total amount of light received by the detection areas
25   201, 204, 205, 208 and 209 of the light detector 151. The differential operation circuit 418 generates a differential signal corresponding to {signal t1-(signal t2+signal t3)}. The differential operation circuit 420 generates a differential signal corresponding to {(signal t1+signal
30   t2)-signal t3)}. Signal t1 is generated by the adder 401, signal t2 is the same as signal s5 which is output from the detection area 209, and signal t3 is generated by the adder 404.

The tracking error signal is a differential signal indicating the difference between signals t1 and t3. Signal t1 is the sum of the signals output from the detection areas

5   **201** and **208** which are disposed left to the division line **301**. Signal t3 is the sum of the signals output from the detection areas **204** and **205** which are disposed right to the division line **303**.

10   Due to the above-described structure, the optical head device shown in Figure **20** can perform recording and reproduction of information such as addresses to and from the optical disk with substantial stability.

15   With reference to Figures **21A**, **21B** and **21C**, an optical head device having a different information reproduction signal generator from the generator shown in Figure **18** will be described.

20   Figure **21A** shows a part of the optical disk having a groove **501** ad a series of pits **502** on the information layer **108** (Figure **1**).

       Figures **21B** and **21C** schematically show a light
25   detector **350** and an information reproduction signal generator **450**.

       Figure **21B** shows a circuit configuration for reproducing information stored in a first address zone **504**
30   of the optical disk in Figure **21A**. Figure **21C** shows a circuit configuration for reproducing information stored in a second address zone **505** of the optical disk in Figure **21A**. The information reproduction signal generator **450** includes an

adder **430** and a differential operation circuit **431** shown in Figure **21B** and also an adder **432** and a differential operation circuit **433** shown in Figure **21C**.

5   The differential operation circuit **431** generates a reproduction signal RFa3 based on expression (23), and the differential operation circuit **433** generates a reproduction signal RFa4 based on expression (24).

10      $$RFa3 = t1 - (t3 + t4) \ldots (23)$$

$$RFa4 = (t1 + t2) - t4 \ldots (24)$$

The reproduction signal RFa3 is used for reproducing
15   the information stored in the first address zone **504**, and the reproduction signal RFa4 is used for reproducing the information stored in the second address zone **505**. The information reproduction signal generator **450** may include a selector for selecting either the reproduction signal RFa3
20   or RFa4.

Hereinafter, comparison between the optical head device shown in Figures **21B** and **21C** and the conventional optical head device regarding the jitter will be described.
25   In the following comparison, the numerical aperture NA of the objective lens is 0.6, the wavelength λ of the light is 0.660 μm, and the space Gp between two adjacent guiding grooves is 1.48 μm. The center line **508** of the series of pits **502** in the first address zone **504** and the center line
30   **509** of the series of pits **502** in the second address zone **505** are each off the center line of the track **507** by 0.37 μm.

In the conventional optical head device, in which

the information is reproduced based on a signal indicating the difference among the signals obtained from each of the areas in the light detector defined by a central division line of the aperture, the jitter obtained by calculation

5   is 6.4%.

        In the optical head device shown in Figures 21B and 21C, the information can be reproduced in the following manner. The division line 302 divides the aperture equally

10   into two. The aperture has a radius of 1. The distance between the division lines 301 and 302 is represented by d, and the distance between the division lines 303 and 302 is also represented by d, where d=0.23. The aperture is divided into two detection areas by the division line 301

15   or 303, and the information is reproduced based on a signal indicating the difference between the signals obtained from the two detection areas, namely, signals RFa3 or RFa4. In such a system, the jitter obtained by calculation is 1.4%. Thus, the optical head device shown in Figures 21B and 21C

20   can improve the jitter by 5% or more compared to the conventional optical head device.

        As described above, in the optical head device shown in Figures 21B and 21C, information stored in the form of

25   a series of pits which are positioned off the track can be reproduced with a sufficiently low level of jitter. Accordingly, a margin against disturbance and the like is increased, and thus information such as addresses can be recorded to and reproduced from the optical disk in the form

30   of pits with satisfactory stability.

        With reference to Figures 22A and 22B, other another optical head device having a different information

reproduction signal generator from the generators shown in Figures **18** and **20** will be described.

5   Figure **22A** shows a part of the optical disk having a groove **501** and a series of pits **502** on the information layer **108** (Figure **1**).

Figure **22B** schematically shows a light detector **351** and an information reproduction signal generator **450**.

10

The information reproduction signal generator **450** includes a differential operation circuit **434**. The differential operation circuit **434** generates a reproduction signal RFa0 based on expression (25).

15

RFa0=t1-t4 ... (25)

The reproduction signal RFa0 is used for reproducing the information stored in the first address zone **504** and
20   the second address zone **505**.

Hereinafter, comparison between the optical head device shown in Figure **22B** and the conventional optical head device regarding the jitter will be described. In the
25   following comparison, the numerical aperture NA of the objective lens is 0.6, the wavelength λ of the light is 0.660 μm, and the space Gp between two adjacent guiding grooves is 1.48 μm. The center line **508** of the series of pits **502** in the first address zone **504** and the center line
30   **509** of the series of pits **502** in the second address zone **505** are each off the center line of the track **507** by 0.37 μm.

In the conventional optical head device, the jitter

obtained by calculation is 6.4% as described above.

In the optical head device shown in Figure **22B**, the jitter obtained by calculation is 2.6%. Thus, the optical head device shown in Figure **22B** can improve the jitter by nearly 4% compared to the conventional optical head device.

As described above, in the optical head device shown in Figure **22B**, information stored in the form of a series of pits which are positioned off the track can be reproduced with a sufficiently low level of jitter. Accordingly, a margin against disturbance and the like is increased, and thus information such as addresses can be recorded to and reproduced from the optical disk in the form of pits with satisfactory stability.

In the optical head device shown in Figure **22B**, it is not necessary to select a signal to be output from the information reproduction signal generator **450** in accordance with whether the information to be reproduced is stored in the first address zone **504** or the second address zone **505**. Accordingly, the optical head device shown in Figure **22B** can be realized with a relatively simple circuit configuration.

With reference to Figures **23A** and **23B**, another optical head device having a different information reproduction signal generator from the generators shown in Figures **18**, **20** and **22** will be described.

Figure **23A** shows a part of the optical disk having a groove **501** and a series of pits **502** on the information layer **108** (Figure **1**).

Figure **23B** schematically shows a light detector **352** and an information reproduction signal generator **450**.

As shown in Figure **23B**, the information reproduction signal generator **450** includes a differential operation circuit **437**, and adders **435** and **436**. The differential operation circuit **437** generates a reproduction signal RFa00 based on expression (26).

$$RFa00=(t1+t3)-(t2+t4) \quad \dots \quad (26)$$

The reproduction signal RFa00 is used for reproducing the information stored in the first address zone **504** and the second address zone **505**.

Hereinafter, comparison between the optical head device shown in Figure **23B** and the conventional optical head device regarding the jitter will be described. The conditions are the same as described above with reference to Figure **22B**.

In the conventional optical head device, the jitter obtained by calculation is 6.4% as described above.

In the optical head device shown in Figure **23B**, the jitter obtained by calculation is 1.2%. Thus, the optical head device shown in Figure **23B** can improve the jitter by nearly 5% compared to the conventional optical head device.

As described above, in the optical head device shown in Figure **23B**, information stored in the form of a series of pits which are positioned off the track can be reproduced

with a sufficiently low level of jitter. Accordingly, a margin against disturbance and the like is increased, and thus information such as addresses can be recorded to and reproduced from the optical disk in the form of pits with
5   satisfactory stability.

In the optical head device shown in Figure 23B, it is not necessary to select a signal to be output from the information reproduction signal generator **450** in accordance
10 with whether the information to be reproduced is stored in the first address zone **504** or the second address zone **505**. Accordingly, the optical head device shown in Figure **23B** can be realized with a relatively simple circuit configuration.
15

(Example 7)
In a seventh example according to the present invention, information which is recorded at a position off the grooves of the optical disk used as an information memory
20 medium is reproduced.

An optical system of the optical head device used in the seventh example has substantially the same structure as the optical system shown in Figure **14** except for including
25 a holographic element **120** in lieu of the holographic element **117** and including a light detector **155** in lieu of the light detector **154**.

Figure **24** shows a pattern for dividing the
30 holographic element **120**, detection areas of the light detector **155**, and cross sections of the zero-the order light **108a**, the minus first-order diffraction light **108b** and the plus first-order diffraction light **108o** on the light

detector **155**.

The holographic element **120** is divided into a plurality of strip-shaped areas **A**, **a**, **B**, **b**, **C**, **c**, **D**, **d**, and **X**. These letters indicating the strip-shaped areas also indicate the corresponding cross sections of the zero-the order light **108a**, the minus first-order diffraction light **108b** and the plus first-order diffraction light **108c**. The minus first-order diffraction light **108b** obtained from the areas represented by capital letters **A**, **B**, **C** and **D** is collected farther from the minus first-order diffraction light **108b** obtained from the areas represented by lower case letters **a**, **b**, **c** and **d** with respect to the detection lens **116**. The light corresponding to the areas **X** is not diffracted and thus is entirely transmitted through the areas **X** as the zero-the order light **108a**.

The minus first-order diffraction light **108b** is received by detection areas **230** through **232**, and the plus first-order diffraction light **108c** is received by detection areas **233** through **236**. The zero-the order light **108a** is received by a detection area **237**. A focusing error signal is generated by a signal obtained in accordance with the amount of light received by the detection areas **230** through **232**.

The detection areas **233** through **236**, respectively, generate signals t1 through t4 in accordance with the amount of light received. The detection area **237** generates signal x0 in accordance with the amount of light received. A tracking error signal THE for the groove of the optical disk **105** (Figure **14**) is obtained based on expression (27).

$$THE=(t1+t4)-(t2+t3) \ldots (27)$$

The ratio of the diffraction efficiency of the plus first-order diffraction light **108c** (obtained by the detection areas other than the detection areas **X** of the holographic element **120**) with respect to the zero-the order light transmitted through the detection areas **X** is indicated by β. An information reproduction signal RF is obtained by expression (28).

$$RF=t1+t2+t3+t4+\beta \cdot x0 \ldots (28)$$

For reproducing information stored in the optical disk having the structure shown in Figure **19A**, when the focal point of the light from the objective lens is in the track **507** of the first address zone **504**, the information stored in the optical disk in the form of the pits **502** is reproduced by obtaining signal RFa1 by the operation represented by expression (29).

$$RFa1=(s1+s4)-(s2+s3+\beta \cdot x0) \ldots (29)$$

When the focal point of the light from the objective lens is in the track **507** of the second address zone **505**, the information stored in the optical disk in the form of the pits **502** is reproduced by obtaining signal RFa2 by the operation represented by expression (30).

$$RFa2=(s1+s4+\beta \cdot x0)-(s2+s3) \ldots (30)$$

Through such a system, the optical head device shown in Figure **24** provides the same effect as the effect described in the sixth example. As described above, in the optical

head device shown in the seventh example, information stored in the form of a series of pits which are positioned off the track can be reproduced with a sufficiently low level of jitter. Accordingly, information such as addresses can
5   be recorded to and reproduced from the optical disk in the form of pits with satisfactory stability.

(Example 8)

In an eighth example according to the present
10   invention, characteristics of a tracking error signal THE are improved using a holographic element. The focusing error signal is generated by the spot size method, and the tracking error signal is generated by the push-pull method.

15   Figure 25 is a schematic view of an optical system of an optical head device according to the eighth example. The optical head device shown in Figure 25 operates in the following manner.

20   Linearly polarized light emitted by a semiconductor laser 101 (used as a light source) is collimated by a collimator lens 103 as light 101a, the collimator lens 103 being included in a collection optical system. The collimated light 101a enters a polarization anisotropic
25   holographic element 121 employed as a light division element. The holographic element 121 is positioned so that the light 101a from the semiconductor laser 101 is not diffracted by the holographic element 121. The light 01a transmitted through the holographic element 121 is circularly polarized
30   by a 1/4-wave plate 122. The light 101a is then collected by an objective lens 104 on an information layer 108 of an optical disk 105 used as an information memory medium.

The light is reflected and/or diffracted by the information layer **108** of the optical disk **105** as light **108a** is transmitted back through the objective lens **104** to be collimated. The collimated light **108a** is transmitted

5 through the 1/4-wave plate **122** to be converted into linearly polarized light which runs in a direction perpendicular to the direction of the light **101a** from the semiconductor laser **101**. The linearly polarized light is then diffracted by the polarization anisotropic holographic element **121** into minus

10 first-order diffraction light **108b** and plus first-order diffraction light **108c**. The minus first-order diffraction light **108b** and the plus first-order diffraction light **108c** are converged by the collimator lens **103**. Then, the minus first-order diffraction light **108b** is received by a light

15 detector **156**, and the plus first-order diffraction light **108c** is received by a light detector **157**.

A holding device **106** integrally holds the polarization anisotropic holographic element **121**, the

20 1/4-wave plate **122** and the objective lens **104**. An actuator **107** moves the holding device **106** in accordance with the fluctuation or decentration of the optical disk **105**.

Figure **26** shows a pattern for dividing the

25 polarization anisotropic holographic element **121**, detection areas of the light detectors **156** and **157**, and cross sections of the minus first-order diffraction light **108b** and the plus first-order diffraction light **108c** respectively on the light detectors **156** and **157**.

30

The holographic element **121** is divided into a plurality of strip-shaped areas **A**, **a**, **B**, and **b**. These letters indicating the strip-shaped areas also indicate the

corresponding cross sections of the minus first-order diffraction light **108b** and the plus first-order diffraction light **108c** on the light detectors **156** and **157**. The minus first-order diffraction light **108b** obtained from the areas represented by capital letters **A** and **B** is collected farther from the minus first-order diffraction light **108b** obtained from the areas represented by lower case letters **a** and **b** with respect to the collimator lens **103**.

The optical system shown in Figure **25** and the holographic element **121** are designed so that, when the focal point FO of the light from the objective lens **104** is on the information layer **108** of the optical disk **105**, the cross section of the minus first-order diffraction light **108b** obtained from the areas represented by the capital letters **A** and **B** has an equal size to that of the cross section of the minus first-order diffraction light **108b** obtained from the areas represented by the lower case letters **a** and **b**.

Detection areas **238** through **243** respectively generate signals f1 through f6 in accordance with the amount of light received. A focusing error signal FE is obtained b an operation represented by expression (31) or (32).

$$FE=(f1+f3+f5)-(f2+f4+f6) \ ... \ (31)$$

$$FE=f5-f2 \ ... \ (32)$$

When the information layer **108** is distanced from the objective lens **104** to be beyond the focal point FO of the light from the objective lens **104**, the cross sections **A** and **B** of the minus first-order diffraction light **108b** are decreased, and the cross sections **a** and **b** of the minus

first-order diffraction light **108b** are increased.
Accordingly, the amplitudes of signals f1, f3 and f5 reduce
and the amplitudes of signals f2, f4 and f6 increase. The
amplitude of the focusing error signal FE reduces.

5

When the information layer **108** approaches the
objective lens **104** to be between the objective lens **104** and
the focal point F0 of the light from the objective lens **104**,
the cross sections **A** and **B** of the minus first-order
10   diffraction light **108b** are increased, and the cross sections
a and **b** of the minus first-order diffraction light **108b** are
decreased. Accordingly, the amplitudes of signals f1, f3
and f5 increase and the amplitudes of signals f2, f4 and
f6 reduce. The amplitude of the focusing error signal FE
15   increases.

In such a system, focusing control for maintaining
the focal point F0 on the information layer **108** is realized.

20   Detection areas **244** and **245** of the light detector
157 respectively generate signals t1 and t2 in accordance
with the amount of light received. The tracking error signal
TE1 is obtained by expression (33) by the push-pull method.

25   TE1=t1-t2 ... (33)

The tracking error signal TE1 substantially
indicates the difference in light amount between the lined
areas and the blank areas of the holographic element **121**
30   in Figure **26**.

An RF signal for reproducing the information is
obtained as RFf by expression (34), as RFt by expression

(35), or as the sum of RFf and RFt.

RFf=f1+f2+f3+f4+f5+f6 ... (34)

RFt=t1+t2 ... (35)

Hereinafter, comparison between the optical head device shown in Figure 26 and the conventional optical head device regarding he degree of asymmetry of the upper and lower amplitudes of the tracking error signal will be described.

The optical disk includes a plurality of tracks having grooves or a series of pits. The distance from the center of a track to the center of an adjacent track is indicated by Tp. Where the numerical aperture of the objective lens 104 (Figure 25) is NA and the wavelength of the light is λ, expression (36) is fulfilled in the eighth example.

$$\lambda/(NA \cdot Tp) \geq 1 \ldots (36)$$

A feature of the optical head device in the eighth example is that areas included in about 0.1 wide parts sandwiching the division line which runs through the center of the aperture and is parallel to the grooves of the optical disk are exchanged with each other, and areas included in about 0.1 wide parts at ends of the aperture are exchanged with each other for the operation, as described in detail below.

In the case of a polarization anisotropic holo-

graphic element, the strip-shaped areas **A** and **a** are alternately arranged in the part left to the central division line **302**, and the strip-shaped areas **B** and **b** are alternately arranged in the part right to the central division line **302**. In the case of the holographic element shown in Figure **26**, one strip-shaped area **A** and one strip-shaped area **b** sandwiching the central divisional line **302** are exchanged with each other. Along the ends of the aperture, the strip-shaped areas **A** and **a** are exchanged with the strip-shaped areas **B** and **b**.

In the case where the strip-shaped areas are not exchanged as described above (i.e., in the conventional optical head device), the degree of asymmetry of the upper and lower amplitudes of the tracking error signal is as follows. The degree of asymmetry is measured under the conditions where the numerical aperture NA of the objective lens is 0.5, the wavelength λ of light is 0.795 μm, the light intensity at the end of the objective lens is 10% higher than the light intensity at the center of the objective lens, the thickness of the optical disk is 1.2 mm, and the distance Tp between the centers of two adjacent tracks Tp is 1.6 μm. When the objective lens shifts by 500 μm, the degree of asymmetry is 53%. When the radial tilt is 1.0 degrees, the degree of asymmetry is 24%.

In the case of the optical head device shown in Figure **26**, the degree of asymmetry is as follows where each of the strip-shaped areas has a width of 0.1 times the radius of the objective lens and Tp is 1.6 μm. When the objective lens shifts by 500 μm, the degree of asymmetry is 46%. When the radial tilt is 1.0 degrees, the degree of asymmetry is 12%. As can be understood, when the objective lens shifts by

500 μm, the degree of asymmetry in the optical head device shown in Figure 26 is 13% lower than that of the conventional optical head device. When the radial tilt is 1.0 degrees, the degree of asymmetry in the optical head device shown in Figure 26 is 50% lower than that of the conventional optical head device. Due to such a significant reduction in the degree of asymmetry, the tracking control is stabilized, and a margin against disturbance and the like is increased. Thus, information can be recorded and reproduced with a sufficiently low error ratio.

In an optical head device in which the aperture is simply divided into two, the difference between the focus position at which the amplitude of the information reproduction signal is maximum and the focus position at which the amplitude of the tracking error signal is maximum is 1.5 to 1.0 μm. In the optical head device shown in Figure 26, such a difference is 1.0 to 0.5 μm. The reduction in such a difference also realizes a lower error ratio for information recording and reproduction while maintaining the tracking control stable.

In the eighth example, the polarization anisotropic holographic element is used as a light division element. Alternatively, a holographic without polarization anisotropy may be used. The same effect can be obtained.

In the eighth example, the polarization anisotropic holographic element used as a light division element is driven integrally with the objective lens. The light division element may be provided at any position between the collection optical system and the light detector. As the objective lens moves in accordance with the decentration

of the track of the optical disk or the like, the relative positions of the light division element and the objective lens changes. By the pattern for dividing the holographic element described in the eighth example, the deterioration
5   of the tracking error signal due to this change can be restricted.

(Example 9)

       In a ninth example according to the present
10   invention, the degree of asymmetry of the tracking error signal is corrected. The optical system of the optical head device used in the ninth example is identical with that of the optical system shown in Figure 25 except that a polarization anisotropic holographic element 123 is used
15   in lieu of the holographic element 121. The structure and operation of the optical system will be omitted.

       Figure 27 shows the holographic anisotropic element 123 used in the ninth example. The aperture is a circle
20   having a radius of 1. Strip-shaped area a each having a width of about 0.6 and strip-shaped areas B each having a width of about 0.6 which sandwich a central division line of the aperture are exchanged with each other. The central division line is parallel to the track. A tracking error
25   signal indicates the difference between the amount of light incident on the strip-shaped areas A and a (lined areas) and the amount of light incident on the strip-shaped areas B and b (white areas). In Figure 27, two lined areas and two white areas are exchanged with each other.
30
       The degree of asymmetry of the upper and lower amplitudes of the tracking error signal is as follows under the conditions where the numerical aperture NA of the

objective lens is 0.5, the wavelength λ of light is 0.795 µm, the diameter of the objective lens is 4 mm, the light intensity at the end of the objective lens is 10% higher than the light intensity at the center of the objective lens,

5   and the distance Tp between the centers of two adjacent tracks is 1.6 µm. In the case of the conventional optical head device in which the strip-shaped areas are not exchanged, when the objective lens shifts by 500 µm, the degree of asymmetry is 53%. When the radial tilt is 1.0 degrees, the

10   degree of asymmetry is 24%.

According to one aspect of the optical head device shown in Figure **27**, for example, the lined areas having a total width of 1.2 mm are exchanged with the white areas

15   having a total width of 1.2 mm with the central division line at the center. When the objective lens shifts by 500 µm, the degree of asymmetry is 45%. When the radial tilt is 1.0 degrees, the degree of asymmetry is 14%. As can be understood, when the objective lens shifts by 500 µm, the

20   degree of asymmetry in the optical head device shown in Figure **27** is about 15% lower than that of the conventional optical head device. When the radial tilt is 1.0 degrees, he degree of asymmetry in the optical head device shown in Figure **27** is about 42% lower than that of the conventional

25   optical head device.

The optical head device in the ninth example has a greater effect against the shift of the objective lens even than the optical head device shown in Figure **26** in the eighth

30   example. Accordingly, the tracking control is further stabilized, and a margin against disturbance and the like is increased. Thus, information can be recorded and reproduced with a substantially low error ratio.

In the ninth example, the polarization anisotropic holographic element is used as a light division element. Alternatively, a holographic without polarization anisotropy may be used. The same effect can be obtained.

In the first through ninth examples, an optical disk is used as an information memory medium. The same effect is achieved when an optical card or the like is used.

In the first through ninth examples, an infinite-type collection optical system including a collimator lens and an objective lens is used. The same effect can be achieved with a limited-type collection optical system including an objective lens which also acts as a collimator lens without using a separate collimator lens.

(Example 10)

In a tenth example according to the present invention, an inclination detection apparatus will be described.

Figure **28** schematically shows an inclination detection apparatus in the tenth example. The inclination detection apparatus operates in the following manner.

A linearly polarized scattering beam emitted by a semiconductor laser **101** used as a light source is collimated by a collimator lens **103** and then incident on a polarizing beam splitter **130** employed as a beam branching element. The beam is entirely transmitted through the polarizing beam splitter **130** as a beam **70** and then transmitted through a 1/4-wave plate **122** to be circularly polarized. The

circularly polarized light is collected on an information memory medium **105** by an objective lens used as a collection light system. The beam **70** is diffracted and/or reflected by the information memory medium **105** is transmitted back through the objective lens **104** and then through the 1/4-wave plate **122** to be converted into a linearly polarized beam (also indicated by reference numeral **70**) which runs in a direction perpendicular to the direction of the light from the semiconductor laser **101**. The beam **70** is then entirely reflected by the polarizing beam splitter **130** and then made incident on a polarizing beam splitter **132**. The beam **70** is divided into two beams **70A** and **70B**. The beam **70B** is detected by a light detector **159**. The beam **70A** is converged by a detection lens **133**. The converged beam **70A** is transmitted through a plane-parallel beam splitter **134** and then received by a light detector **158**. The beam **70A** is provided with a non-point aberration for detecting a focusing error signal when passing through the plane-parallel beam splitter **134**. The beam **70A** received by the light detector **158** and the beam **70B** received by the light detector **159** are respectively converted into electric signals in accordance with the amounts thereof. The electric signals which are output from the light detectors **158** and **159** are input to a signal processing section **700** (Figure **29**).

Figure **29** shows a configuration of the signal processing section **700**.

The light detector **158** includes four detection areas **158A** through **158D**, and the light detector **159** includes two detection areas **159A** and **159B**. The signals which are output from the detection areas **158A** and **158C** are current-voltage converted by a current-voltage converter **854**, and the

signals which are output from the detection areas **158B** and **158D** are current-voltage converted by a current-voltage converter **853**. The signal which is output from the detection area **159A** is current-voltage converted by a current-voltage

5   converter **852**, and the signal which is output from the detection areas **159B** is current-voltage converted by a current-voltage converter **851**.

The difference between the signals output from the
10   current-voltage converters **853** and **854** is obtained by an operation section **874**. The signal from the operation section **874** is output from a terminal **811** as a focusing error signal.

15   The difference between the signals output from the current-voltage converters **851** and **852** is obtained by an operation section **871**. The signal from the operation section **871** is output from a terminal **812** as a tracking error signal.
20

The system for generating the focusing error signal, which is referred to as the non-point aberration method, and the system for generating the tracking error signal, which is referred to as the push-pull method, are both known
25   and will not described in detail.

The focusing error signal is sent to an actuator **107** for driving the focusing control, and the tracking error signal is sent to an actuator **107** for driving the tracking
30   control.

The optical system and the information memory medium **105** are relatively positioned so that the beam **70** from the

semiconductor laser **101** is focused on a desired position on the information memory medium **105**.

5 The current-voltage converters **851** and **852** are added together by an adder **891**. The signal from the adder **891** is sent to sample and hold sections **821** and **822**. The sample and hold sections **821** and **822** perform the sample-and-hold operation respectively at the timing of timing signals Sa1 and Sa2, which are generated by a trigger signal generator

10 **801**. The difference between the signals from the sample and hold sections **821** and **822** is obtained by an operation section **872** and then output from a terminal **813** as an inclination detection signal.

15 Figure **30** shows the relationship between a pattern on the information memory medium **105** and the timing of the timing signal generated by the trigger signal generator **801**. In Figure **30**, letter **x** represents the direction perpendicular to the track storing the information, and

20 letter **y** represents the direction parallel to the track storing the information. Letter **z** represents the direction perpendicular to both directions **x** and **y**.

The information memory medium **105** includes first

25 pattern areas having marks and spaces and second pattern areas having guide grooves Gn-1, Gn and Gn+1. The first pattern areas and the second pattern areas are arranged alternately in the direction **y**. In the second pattern areas, each represent a guide groove.

30

Letter Gp represents a distance between centers of two adjacent guide grooves. Data can be stored in the guide grooves as well as between the grooves in order to increase

the amount of information which can be stored. Symbols Tn-2 ... Tn+2 each represent a track for storing information. Where the distance between centers of two adjacent tracks is tp, Gp and tp have the relationship of: Gp=2·tp. In this example, Gp=1.48 μm, the wavelength λ of the beam **70** from the semiconductor laser **101** is 650 nm, and the numerical aperture NA of the objective lens **104** (Figure **28**) is 0.6.

In the first pattern areas, marks **541** and **542** are formed with a distance from each other of ±Gp/4 in the direction **x**. The timing signals Sa1 and Sa2 generated by he trigger signal generator **801** respectively correspond to the marks **541** and **542**. The tracking error signal is generated using a signal obtained from the light detector **159** when the second pattern areas are irradiated by the beam **70** collected by the objective lens **104**. Where the signal output from the terminal **812** is a tracking error signal, when the angle made by the beam **70** collected by the objective lens **104** and the information memory medium **105** changes, the signal output from the terminal **813** changes in correspondence with the change.

Figure **31A** is a schematic partial view of the track shown in Figure **30**. In Figure **31A**, (A) and (B) each represent a path of the beam collected by the objective lens **104**. When the beam runs the path (A), the signal which is output from the adder **891** (Figure **29**) has a waveform shown in Figure **31B**, and the signal which is output from the operation section **872** (Figure **29**) has a waveform shown in Figure **31C**. When the beam runs the path (B), the signal which is output from the adder **891** has a waveform shown in Figure **31D**, and the signal which is output from the operation section **872** has a waveform shown in Figure **31E**.

In the case of Figure **31B**, the values of the timing signals Sa1 and Sa2 from the adder **891** are equal to each other. Accordingly, as shown in Figure **31C**, the output from the operation section **872** after the timing signal Sa2 is output is zero. In the case of Figure **31D**, the values of the timing signals Sa1 and Sa2 from the adder **891** are different from each other. Accordingly, as shown in Figure **31E**, the output from the operation section **872** after the timing signal Sa2 is not zero.

Figure **32** is a graph illustrating the inclination detection signal output from the terminal **813** with respect to the angle made by the beam **70** collected by the objective lens **104** and the information memory medium **105** in the case where Gp=1.48 μm and Gp=0.83 μm. In Figure **32**, the inclination is zero when the axis of the beam **70** collected by the objective lens **104** is parallel to the direction z, i.e., perpendicular to the information memory medium **105**.

In both of the cases where Gp=1.48 μm and Gp=0.83 μm, the inclination detection signal can be detected as long as the inclination of the angle is 1 degree or less. Such a level of detection sensitivity is 5 times higher than in the conventional inclination detection apparatus. The inclination detection apparatus in the tenth example has such a high detection sensitivity since the apparatus operates based on the principle that the phase of the beam is diffracted by the pattern and guide grooves of the information memory medium **105**. The detection sensitivity is higher when Gp=1.48 μm than when Gp=0.83 μm. The apparatus utilizes the principle that detection sensitivity is related to the pattern of the information

memory medium **105** and overlap of plus first-order diffraction light and minus first-order diffraction light obtained from the light. The conditions under which the plus first-order diffraction light and the minus first-order diffraction light overlap are represented by $NA > \lambda/Gp$. The detection sensitivity of the inclination of the angle is improved when the optical system has the relationship of $NA > \lambda/Gp$.

The inclination detection apparatus in the tenth example realizes detection of the inclination of the angle made by the beam collected by the collection optical system and the information memory medium **105** with a higher precision than in conventional inclination detection apparatuses. Moreover, since the inclination can be detected using a light detector for detecting a tracking error signal, a separate device for detecting the inclination is not necessary. Thus, a low-cost and compact inclination detection apparatus can be provided.

In the tenth example, the signal which is output from the terminal **812** is used as a tracking error signal and the signal which is output from the terminal **813** is used as an inclination detection signal. Alternatively, the signal which is output from the terminal **813** may be used as a tracking error signal and the signal which is output from the terminal **812** may be used as an inclination detection signal. Use of the signal output from the terminal **813** is advantageous in, for example, an optical head device without a driving section for correcting the inclination of the angle made by the beam **70** collected by the objective lens **104** and the information memory medium **105**. Even when such an inclination occurs, the positional deviation between the guide grooves and the

track is substantially small, and thus the compatibility between different types of optical head devices and different types of information memory mediums is improved.

5   In the case where the inclination detection signal is a control signal of a driving section **135** (Figure **28**) for driving the optical system and controls so that the beam **70** collected by the objective lens **104** and the information memory medium **105** made a prescribed angle, an optical head 10   device for stably reading information even from a significantly curved information memory medium. Through control of the intensity of the beam for recording the information on the information memory medium **105** in accordance with the inclination detection signal, 15   satisfactory recording of information can be performed on a significantly curved information memory medium.

          In the tenth example, the light detector **158** for detecting a focusing error signal and a tracking error signal 20   and the light detector **159** for generating an inclination detection signal are separately provided. Alternatively, the optical system shown in Figure **44** having one light detector for generating a focusing error signal and a tracking error signal as well as an inclination detection 25   signal can be used.

(Example 11)
          Figure **33** shows a configuration of a signal processing section **701** of an inclination detection apparatus 30   in an eleventh example according to the present invention.

          The signal processing section **701** is used in lieu of the signal processing section **700** shown in Figure **29** in

the inclination detection apparatus.

The signal processing section **701** is different from the signal processing section **700** in that the former includes a sample and hold section **823**, a variable gain amplification section **831** and the operation section **873** and has a different timing signal output from a trigger signal generator **802**. The sample and hold section **823** performs the sample-and-hold operation at the timing of a timing signal Sa3 which is output from the trigger signal generator **802**. As shown in Figure **30**, the timing of the timing signal Sa3 corresponds to the space in the first pattern area of the information memory medium **105**. A signal which is sampled and held by the sample and hold section **823** is, for example, a signal in proportion to the offset which is caused to the tracking error signal in an optical system for driving the objective lens for tracking control as shown in Figure **35** (infra) when the objective lens moves. The signal which is output from the sample and hold section **823** is, for example, sent to the variable gain amplification section **831** and adjusted to have a desirable level. The signal output from the variable gain amplification section **831** is sent to the operation by the operation section **873**. The difference between the signal from the variable gain amplification section **831** and the signal from the operation section **871** is obtained by the operation section **873**. The signal output from the operation section **873** is output from the terminal **812**. By obtaining the difference between the signal from the variable gain amplification section **831** and the signal from the operation section **871**, the offset caused to the tracking error signal is eliminated even when the objective lens moves by tracking control. Accordingly, stable tracking control can be performed, and thus an inclination detection signal is

accurately detected.

(Example 12)

Figure **34** shows a configuration of an information memory medium in an inclination detection apparatus in a twelfth example according to the present invention. Figure **35** is a schematic view of a signal processing section **702** of the inclination detection apparatus.

The information memory medium shown in Figure **34** is different from the information memory medium shown in Figure 30 in that the former has a plurality of marks **541** and a plurality of marks **542**.

Sample and hold sections **824** through **827** in the signal processing section **702** sample and hold the signal from the adder **891** at the timing of timing signals Sa4 through Sa7. The timing signals Sa4 through Sa7 respectively correspond to the marks **541** and **542** and mirror surfaces thereof. The timing signals are generated by a trigger signal generator **803**. The difference between signals output from the sample and hold sections **824** and **825** is obtained from an operation section **875**, and the difference between signals output from the sample and hold sections **826** and **827** is obtained from an operation section **876**. The difference between the signals from the operation sections **875** and **876** is obtained by the operation section **872** and output from the terminal **813** as an inclination detection signal.

The inclination detection apparatus using the information memory medium shown in Figure **34** in the twelfth example provides an inclination detection signal at a higher

level of detection sensitivity than the inclination
detection apparatus using the information memory medium
shown in Figure **30** in the tenth example.

5   (Example 13)

Figure **36** schematically shows an optical head device
in the thirteenth example.   The optical head device operates
in the following manner.

10   A semiconductor laser **101** used as a light source
emits a light beam **70** having a wavelength λ of 650 nm.   The
linearly polarized scattering beam emitted by the
semiconductor laser **101** is collimated by a collimator lens
103 and then made incident on a beam splitter **136** employed
15   as a beam branching element.   The beam splitter **136** is a half
mirror, the optical characteristics thereof do not rely on
the polarization direction of the incident beam.   Half of
the intensity of the beam **70** incident on the beam splitter
136 is transmitted through the beam splitter **136** and then
20   incident on a polarization filter **137**.

Figure **37** shows the polarization filter **137**. The
polarization filter **137** includes two areas **137A** and **137B**.
The area **137A** allows transmission of 100% of the light
25   polarized in direction **x** but blocks 100% of the light
polarized in direction **y**.   The area **137B** allows transmission
of 100% of the light polarized in the direction **x** and also
100% of the light polarized in the direction **y**.   The
direction **x** is a radial direction of the information memory
30   medium **105** (Figure **36**) and is perpendicular to the tangent
to the track for storing the information.   The direction **y**
is parallel to the tangent to the track of the information
memory medium **105** and is perpendicular to the radial

direction thereof. Direction z is perpendicular to both of the directions x and y and is parallel to the axis of the beam 70.

5   In Figure 37, reference numeral 70R denotes an image of the aperture of the objective lens 104 (Figure 36). Reference numeral 70S indicates the size of the area 137B. Since the size 70S is smaller than the image 70R, the effective numerical aperture NA of the objective lens 104

10   with respect to the beam 70 polarized in the direction y (i.e., the effective numerical aperture NA of the beam 70 when being collected by the objective lens 104) reduces. In the thirteenth example, the effective numerical aperture NA of the objective lens 104 with respect to the light

15   polarized in the direction x is 0.6, and the effective numerical aperture NA of the objective lens 104 with respect to the light polarized in the direction 7 is 0.4. A beam for which the effective numerical aperture of the objective lens 104 is 0.6 is referred to as a first beam, and a beam

20   for which the effective numerical aperture of the objective lens 104 is 0.4 is referred to as a second beam. In order to polarize the beam in the directions x and y, a laser oscillating in both the TE and TM modes can be used as the semiconductor laser 101. In the case where a semiconductor

25   laser oscillating only either the TE or TM mode is used, the beam can be polarized in the direction x or y by locating the semiconductor laser 101 so that the polarization direction is slightly off the direction x or y. Alternatively, the beam emitted from the semiconductor laser

30   101 may be incident on the wave plate to be circularly or elliptically polarized. In this example, the semiconductor laser 101 is position so that the polarization direction thereof is slightly off the direction x.

Referring again to Figure **36**, the beam **70** transmitted through the polarization filter **137** is incident on the objective lens **104** included i the collection optical

5   system and collected on the information memory medium **105**. The beam **70** diffracted and/or reflected by the information memory medium **105** is transmitted back through the objective lens **104** and then through the polarization filter **137**. The beam **70** is then incident on the beam splitter **136**, which

10   reflects the half of the intensity of the beam **70**. The beam **70** reflected by the beam splitter **136** is incident on a polarization beam splitter **130**. The polarization beam splitter **130** allows transmission of almost 100% of the light polarized in the direction **x** (beam **70A**), and reflects almost

15   100% of the light polarized in the direction **y** (beam **70B**). The beam **70B** is detected by a light detector **159**.

The beam **70A** is converged by a detection lens **133**. The converged beam **70A** is transmitted through a plane-

20   parallel beam splitter **134** and then received by a light detector **158**. The beam **70A** is provided with a non-point aberration for detecting a focusing error signal when passing through the plane-parallel beam splitter **134**. The beam **70A** received by the light detector **158** and the beam

25   **70B** received by the light detector **159** are respectively converted into electric signals in accordance with the amounts thereof. The electric signals which are output from the light detectors **158** and **159** are input to a signal processing section **704** (Figure **38**).

30

Figure **38** shows a configuration of the signal processing section **704**.

The light detector 158 includes four detection areas 158A through 158D, and the light detector 159 includes two detection areas 159A and 159B. The signals which are output from the detection areas 158A and 158C are current-voltage

5   converted by a current-voltage converter 854, and the signals which are output from the detection areas 158B and 158D are current-voltage converted by a current-voltage converter 853. The signal which is output from the detection area 159A is current-voltage converted by a current-voltage

10   converter 852, and the signal which is output from the detection areas 159B is current-voltage converted by a current-voltage converter 851.

The difference between the signals output from the

15   current-voltage converters 853 and 854 is obtained by an operation section 872. The signal from the operation section 872 is output from a terminal 812 as a focusing error signal.

20   The difference between the signals output from the current-voltage converters 851 and 852 is obtained by an operation section 871. The signal from the operation section 871 is output from a terminal 811 as a tracking error signal.

25

The focusing error signal is sent to an actuator 107 for driving the focusing control, and the tracking error signal is sent to an actuator 107 for driving the tracking control.

30

The optical system and the information memory medium 105 are relatively positioned so that the beam 70 from the semiconductor laser 101 is focused on a desired position

on the information memory medium **105**.

The information recorded on the information memory
medium **105** is obtained by adding the signals output from
5   the current-voltage converters **853** and **854**.

The information memory medium **105** has guide grooves
for realizing detection of the tracking error signal. The
distance Gp between centers of two adjacent guide grooves
10   is 1.48 μm. In the case where the effective numerical
aperture NA of the objective lens **104** with respect to the
first beam for reading information stored in the information
memory medium **105** is 0.6 and the effective numerical aperture
NA of the objective lens **104** with respect to the second beam
15   for detecting the tracking error signal is 0.4,
substantially no phase shift occurs to the tracking error
signal even when the angle made by the beam **70** collected
by the objective lens **104** and the information memory medium
105 is inclined from the normal angle. Accordingly, the
20   off-track hardly occurs. The optical head device in the
thirteenth example improves the compatibility between
different types of optical head devices and different types
of information memory mediums. A phase shift caused to the
tracking error signal when the angle made by the beam **70**
25   collected by the objective lens **104** and the information
memory medium **105** is inclined from the normal angle is
conspicuous when the distance Gp and the numerical aperture
NA have the relationship of $Gp > \lambda/NA$. Accordingly, the
optical head device in the thirteenth example is configured
30   to have the relationship of $Gp < \lambda/NA$ in order to obtain a
satisfactory tracking error signal.

In the optical head device in the thirteenth example,

the two beams with respect to which the effective numerical apertures of the objective lens **104** are different are generated so as to have exactly the same axis under any condition, by using the difference in polarization. Due to

5   such a system, the adjustment required when assembling the optical head device in the thirteenth example is not more complicated than in the case of the conventional optical head device despite radiation of the two beams toward the information memory medium **105**.

10

Since the optical head device in this example has no restriction in the method for detecting a focusing error signal, the focusing error signal may be detected using the second beam. In such a case, the wave surface for realizing

15   detection of the focusing error signal such as a non-point aberration can be provided to the second beam. Since the effective numerical aperture NA of the objective lens with respect to the second beam is smaller than that with respect to the first beam, the aberration on the wave surface is

20   also smaller. In the case where the focusing error signal is detected using the second beam, less noise is mixed to the focusing error signal when the beam collected by the objective lens crosses the track on the information memory medium than in the case where the focusing error signal is

25   detected using the first beam. Accordingly, the focusing control can be more stable.

In the thirteenth example, the beam splitter **136** is a half mirror. Since the optical head device in this example

30   is not influenced by the characteristics of the beam splitter **136** such as reflectance or transmittance, a beam splitter having a transmittance of 70 to 90% and a reflectance of 30 to 10% may be used. A beam splitter **136** formed of a half

mirror is appropriate for an optical head device used only for reproduction since the signals from the light detectors **158** and **159** are maximum. A beam splitter having a transmittance of 70 to 90% is appropriate for an optical 5 head device used both for recording and reproduction since the amount of light running from the semiconductor laser **101** to the information memory medium **105** increases.

In the thirteenth example, the information memory 10 medium **105** has continuous guide grooves as a pattern for realizing detection of the tracking error signal. Alternatively, separate marks or guide grooves may be formed on the information memory medium **105**. In such a case, the sample and hold section can be provided on the input side 15 of the operation section **871** of the signal processing section **704**.

(Example 14)
Figure **39** is a schematic view of an optical head 20 device in a fourteenth example according to the present invention.

In this example, focusing control and tracking control are performed by driving the objective lens **104** by 25 actuators **107** for focusing control and tracking control. The objective lens **104** and the polarization filter **137** are integrally driven by the actuators **107**.

The beam **70** diffracted and/or reflected by the 30 information memory medium **105** and then reflected by the beam splitter **136** is collected by the detection lens **133**. The beam **70** is converted by the detection lens **133** and incident on a holographic element **138**. The holographic element **138**

divides the beam **70** into a zero-the order beam **70C** and two first-order detection beams **70D** and **70E**.   The beams **70C, 70D** and **70E** are detected by a light detector **160**.

5   Figure **40** schematically shows the pattern of an off-axis fresnel zone plate formed on the holographic element **138**.   When the beam **70** collected by the objective lens **104** is focused on the information memory medium **105**, the first-order diffraction beam **70D** is focused before the light detector **160**, and the first-order diffraction beam **70E** is focused beyond the light detector **160**.   The diffraction efficiency of the holographic element **138** relies on the polarization direction.   The holographic element **138** is designed so that, for the beam polarized in the direction **x**, the diffraction efficiency of the zero-the order light is 0% and the diffraction efficiency of each of the plus and minus first-order diffraction beams is 40%, and so that, for the beam polarized in the direction **y**, the diffraction efficiency of the zero-the order light is 100% and the diffraction efficiency of each of the plus and minus first-order diffraction beams is 0%.   The pattern on the holographic element **138** is formed by proton exchange of lithium niobate.

25   Figure **41** shows the relationship between the detection areas of the light detector **160** and the beams **70C** through **70E**.   The light detector **160** has detection areas **160A** through **160H**.   The beam **70C** is received by the detection areas **160A** and **160B**, the beam **70D** s received by the detection areas **160C** through **160E**, and the beam **70E** is received by the detection areas **160F** through **160H**.

In the optical head device in this example, the

signal processing section shown in the thirteenth example with reference to Figure **38** can be used as it is. The signal output from the detection area **160A** is sent to the current-voltage converter **852**, the signal output from the
5   detection area **160B** is sent to the current-voltage converter **851**, the signals output from the detection areas **160D**, **160F** and **160H** are sent to the current-voltage converter **854**, and the signals output from the detection areas **160C**, **160E** and **160G** are sent to the current-voltage converter **853**. The
10   method for detecting the focusing error signal used in this example referred to as the spot size detection method is known as well as the non-point aberration.

In this example, the center of the objective lens
15   **104** and the center of the polarization filter **137** always match each other by integrally driving the objective lens **104** an the polarization filter **137** by the actuator. At this point, the second beam is collected on the information memory medium **105** with little aberration, and thus a tracking error
20   signal with less phase shift and less offset can be obtained even when the angle made by the beam **70** collected by the objective lens **104** and the information memory medium **105** is inclined.

25   Moreover, through use of the holographic element **138**, the focusing error signal and the tracking error signal and the signal indicating the information stored in the information memory medium **105** can be detected by one light detector, and thus a low cost optical head device can be
30   realized.

(Example 15)
In order to reproduce information which is stored

at an off-track position, an optical head device in a fifteenth example according to the present invention has a function of switching a detection area which is used for reproducing information in accordance with a positional relationship between a light collection point and a track storing the information to be reproduced.

In the sixth example, a method for reproducing information recorded at an off-track position is described. In the example described above with reference to Figures 18 through 21C, the detection area is switched over in accordance with the positional relationship between the light collection position on the optical disk and the pits storing the information to be reproduced. In this manner, the information stored in the form of a series of pits which are positioned off the track can be reproduced with a sufficiently low level of jitter. Accordingly, a margin against disturbance and the like is increased, and thus information such as addresses can be recorded to and reproduced from the optical disk in the form of pits with satisfactory stability.

Specifically in the example shown in Figures 19B and 19C, an area, of the pits positioned off the track, which contains less information is reduced, and the signal to be used for reproduction is switched over in accordance with the positional relationship between the light collection point and the pits storing the information to be reproduced. Thus, the reproduction jitter is reduced. In the fifteenth example, an optical head device in another example operating by the same concept will be described.

An optical system of the optical head device in the

fifteenth example has a similar structure and operates in a similar manner to the system shown in Figure 1, and detailed descriptions thereof will be omitted.

5   Figure 51 shows detection areas of the light detector 150 and a circuit configuration of the information reproduction signal generator 450 and the tracking error signal generator 451. Elements similar to those described with reference to Figure 18 in the sixth example will not
10   be described in detail. The light detector 150, also acting as a division element, is divided into three areas by a first division line 301 and a second division line 303. Signal t1 is obtained from the detection areas 201 and 208 (area A; left in Figure 51) outside the division line 301. Signals
15   t2 and t3 are obtained from the detection areas 202, 207, 203 and 206 (area B) sandwiched between the division lines 301 and 303. Signal t4 is obtained from detection areas 204 and 205 (area C; right in Figure 51) outside the division line 303. The structure shown in Figure 51 generates a
20   signal sent to an input of the switch (SW1) 426 as a switch element, i.e., a control input provided by the control circuit 425, in a different manner from the structure shown in Figure 18. The adder 417 receives the signals t2, t3 and t4, and outputs the sum of the signals received, i.e.,
25   signal RFa11 (expression (37)), as a first signal. The adder 419 receives the signals t1, t2 and t3 and outputs the sum of the signals received, i.e., signal RFa12 (expression (38))as a second signal.

30           $RFa11 = t2 + t3 + t4 \quad \ldots \quad (37)$
             $RFa12 = t1 + t2 + t3 \quad \ldots \quad (38)$

        The switch (SW1) 426 receives the signals from the

adders **417** and **419** and outputs either one of the signals.

Information stored in the pits positioned off the track is read in the following manner. As shown in Figure **19A**, the information layer **108** (Figure 1) of the optical disk **105** (Figure 1) has the groove **501** and the series of pits **502**. The track **507** runs along the center of the grooves **501** in zones **503** and **506**. In the first address zone **504**, the center line **508** of the series of pits is off the track **507** in one direction by a prescribed distance. In the second address zone **505**, the center line **509** of the series of pits is off the track **507** in the opposite direction by a prescribed distance.

When the focal point F0 of the light from the objective lens **104** (Figure 1) is in the zone **503** or **506**, the focal point F0 is on the track **507**, for example, on the point **510** in the case where tracking control is performed. While the optical disk **105** (Figure 1) rotates and thus moves with respect to the optical head device, the focal point F0 moves from the point **510** to the point **511**, the point **512**, and the point **513** on an extension of the track **507**. While the focal point F0 is in the first address zone **504** and the second address zone **505**, the tracking error signal is on hold (i.e., disabled).

The address detection circuit **424** (Figure **51**) receives a differential signal from the differential operation circuit **423**. Then, the address detection circuit **424** determines whether the focal point F0 of the light from the objective lens **104** (Figure 1) is in the zone **503** or **506** having the groove **501**, in the first address zone **504** or the second address zone **505**, and outputs an identification

signal indicating the determination result.

The control circuit **425** receives the identification signal from the address detection circuit **424**, and controls switch (SW1) **426** and the switch (SW2) **427** based on the identification signal.

The control circuit **425** controls the switch (SW1) **426** and the switch (SW2) **427** so that, when the focal point F0 of the light from the objective lens is in the zone **503** or **506** having the groove **501**, the switch (SW2) **427** outputs the signal RF which is input from the adder **405**. The control circuit **425** also controls the switch (SW1) **426** and the switch (SW2) **427** so that, when the focal point F0 is in the first address zone **504**, the switch (SW2) **427** outputs the signal RFa11; and so that, when the focal point F0 is in the second address zone **505**, the switch (SW2) **427** outputs the signal RFa12.

Through the above-described control of the control circuit **425**, information (e.g., an address) stored in the optical disk is reproduced in the following manner.

When the focal point F0 is at the point **511** or the like in the first address zone **504**, information stored in the series of pits corresponding to the track **507** is reproduced based on signal which is received in a second prescribed area (area B and area C) to the right of the first division line **301** as shown in Figure **52A**.

When the focal point F0 is at the point **512** or the like in the second address zone **505**, information stored in the series of pits corresponding to the track **507** is

reproduced based on signal which is received in a first prescribed area (area A and area B) to the left of the second division line **303** as shown in Figure **52B**. Herein, the area B sandwiched between the first division line **301** and the second division line **303** is shared by the first prescribed area and the second prescribed area.

Here, it is assumed that the tracks **508** and **509** are each off-track by 0.37 µm with respect to the track **507** in the state where the numerical aperture (NA) of the objective lens = 0.6, the wavelength λ = 0.660 µm, and Tp = 1.48 µm (Tp: distance from the center of a track to the center of an adjacent track). Figure **53** shows the calculation results. Compared to the result obtained by the reproduction method of dividing the detection area along the center of the aperture and switching the signals received by such divided areas (d=0), the jitter is improved by about 0.8% with d=0.2.

Figure **53** demonstrates that the optical head device in this example has the same effect as that of the optical head device shown in Figures **18** and **19A** through **19C**. The effect of the optical head device shown in Figures **18** and **19A** through **19C** can be clearly appreciated from Figure **50**. The optical head device in the fifteenth example reproduces information stored in the pits positioned off the track with a sufficiently low level of jitter. Accordingly, the margin against disturbance and the like is increased, and thus information such as addresses can be reproduced from the optical disk in the form of pits with satisfactory stability.

(Example 16)

Referring to Figure **54**, an optical head device in a sixteenth example according to the present invention

reproduces information with half the area compared to the optical head device in the fifteenth example.

An optical system of the optical head device in the
5   sixteenth example has a similar structure and operates in a similar manner to the optical head device shown in Figure 1, and a detailed description thereof will be omitted. The optical head device in the sixteenth example uses a light detector **1501** in lieu of the light detector **150**.
10

Figure **54** shows detection areas of the light detector **1501** and a circuit configuration of the information reproduction signal generator **450** and the tracking error signal generator **451**. The light detector **1501** is divided
15   into five detection areas **2001** though **2005** by a transverse division line **3004** substantially vertical to the tangent of the track of the optical disk **105** (Figure 1) and longitudinal divisional lines **3001** through **3003** substantially parallel to the tangent of the track. Signals
20   s11 through s15 are obtained in accordance with an amount of light received by the detection areas **2001** though **2005**.

The light detector **1501**, also acting as a division element, is divided into four areas by the transverse
25   division line **3004** and the longitudinal division lines **3001** (first longitudinal division line) and **3003** (second longitudinal division line). The signals s13 and s14 are obtained from detection areas **2003** and **2004** (area B) surrounded by the longitudinal division lines **3001** and **3003**
30   and the transverse division line **3004**. The signal s12 is obtained from the detection area **2002** (area A) surrounded by the longitudinal division line **3001** and the transverse division line **3004** and bordering on the area B. The signal

s15 is obtained from the detection area **2005** (area C) surrounded by the longitudinal division line **3003** and the transverse division line **3004** and bordering on the area B.

5   Information stored in the pits positioned off the track is read in the following manner. As shown in Figure **19A**, the information layer **108** (Figure 1) of the optical disk **105** (Figure 1) includes the groove **501** and the series of pits **502**. The track **507** runs along the center of the

10   grooves **501** in zones **503** and **506**. In the first address zone **504**, the center line **508** of the series of pits is off the track **507** in one direction by a prescribed distance. In the second address zone **505**, the center line **509** of the series of pits is off the track **507** in the opposite direction by

15   a prescribed distance.

In Figure **54**, an adder **4001** receives the signals s11 through s15 and outputs the sum of the signals received. An information reproduction signal RF output from the adder

20   **4001** is represented by expression (39).

$$RF=s11+s12+s13+s14+s15 \ldots (39)$$

The tracking error signal is obtained by the

25   following calculation. An adder **4002** receives the signals s12 and s13 and outputs the sum of the signals received. An adder **4003** receives the signals s14 and s15 and outputs the sum of the signals received. A differential operation circuit **4004** receives the signals from the adders **4002** and

30   **4003** and outputs a differential signal thereof. An output signal TE, i.e., a tracking signal, from the differential operation circuit **4004** is represented by expression (40).

$$TE=(s14+s15)-(s11+s12) \ldots (40)$$

Tracking control is performed using the tracking signal TE.

The adder 417 receives the signals s13, s14 and s15 and outputs the sum of the signals received, i.e., signal RFh1 (expression (41)) as a first signal. The adder 419 receives the signals s12, s13 and s14 and outputs the sum of the signals received, i.e., signal RFh2 (expression (42)) as a second signal.

$$RFh1=s13+s14+s15 \ldots (41)$$
$$RFh2=s12+s13+s14 \ldots (42)$$

The switch (SW1) 426 receives the signals from the adders 417 and 419 and outputs either one of the signals received.

The control circuit 425 controls the switch (SW1) 426 and the switch (SW2) 427 so that, when the focal point FO of the light from the objective lens is in the zone 503 or 506 having the groove 501, the switch (SW2) 427 outputs the signal RF which is input from the adder 401. The control circuit 425 also controls the switch (SW1) 426 and the switch (SW2) 427 so that, when the focal point FO is in the first address zone 504, the switch (SW2) 427 outputs the signal RFh1; and so that, when the focal point FO is in the second address zone 505, the switch (SW2) 427 outputs the signal RFh2. Needless to say, the control circuit 425 can control the switch (SW1) 426 and the switch (SW2) 427 independently from each other in the above-described examples.

Through the above-described control of the control circuit **425**, information (e.g., an address) stored in the optical disk is reproduced in the following manner.

5   When the focal point F0 is at the point **511** or the like in the first address zone **504**, information stored in the series of pits corresponding to the track **508** is reproduced based on the signal which is received in a first prescribed area surrounded by the transverse division line 10   **3004** and the first longitudinal division line **3001** (area B and area C; right bottom).

When the focal point F0 is at the point **512** or the like in the second address zone **505**, information stored in 15   the series of pits corresponding to the track **509** is reproduced based on signal which is received in a second prescribed area surrounded by the transverse division line **3004** and the second longitudinal division line **3003** (area A and area B; left bottom). Herein, the area B sandwiched 20   between the first longitudinal division line **3001** and the second longitudinal division line **3003** is shared by the first prescribed area and the second prescribed area.

Here, it is assumed that the tracks **508** and **509** are 25   each off-track by 0.37 μm with respect to the track **507** in the state where the numerical aperture (NA) of the objective lens = 0.6, the wavelength λ = 0.660 μm, and Tp = 1.48 μm (Tp: distance from the center of a track to the center of an adjacent track). Figure **55** shows the calculation results. 30   Compared to the result obtained by the reproduction method of dividing the detection area along the center of the aperture and switching the signals received by such divided areas (d=0), the jitter is improved by about 1.2% with

d=0.28.

Figure 55 demonstrates that the optical head device
in this example has the same effect as that of the optical
head device shown in Figures 18 and 19A through 19C (Figure
50) and the optical head device shown in Figures 51, 52A
and 52B (Figure 53). The optical head device in the
sixteenth example reproduces information stored in the pits
positioned off the track with a sufficiently low level of
jitter. Accordingly, a margin against disturbance and the
like is increased, and thus information such as addresses
can be reproduced from the optical disk in the form of pits
with satisfactory stability.

In the sixteenth example, the area used for
reproducing the information which is stored off the track
is reduced compared to that in the fifteenth example. Such
a structure is effective when, for example, the manner of
dividing the detection area is restricted. Specifically,
in the case where the number of signal lines connected to
the light detector is restricted due to the restricted size
of the optical head device, some of the signal lines are
used for generating a focusing error signal and some of
signal lines are used for generating a tracking error signal.
In such a case, the light detector cannot be divided as
described in the fifteenth example. The structure in the
sixteenth example using the area for tracking error signal
generation realizes stable information reproduction with
a smaller number of signal lines.

The structure described in the sixteenth example,
by which a signal is provided from an area obtained by
dividing the detection area with a transverse division line

which is substantially vertical to the tangent of the track, can be combined with the structure in the sixth example to provide the above-described effect. As shown in Figures **56A** and **56B** (corresponding to Figures **19B** and **19C**), a calculation similar to the calculation described with reference to Figures **19B** and **19C** is performed based on a signal provided by one of the areas defined by the transverse division line **3004** of the light detector **1501**. As shown in Figures **57A** and **57B** (corresponding to Figures **21B** and **21C**), a calculation similar to the calculation described with reference to Figures **21B** and **21C** is performed based on a signal provided by one of the areas defined by the transverse division line **3004**. Similarly, as shown in Figure **58** (corresponding to Figures **22B**), a calculation similar to the calculation described with reference to Figure **22B** is performed based on a signal provided by one of the areas defined by the transverse division line **3004**. As shown in Figure **59** (corresponding to Figure **23**), a calculation similar to the calculation described with reference to Figure **23** is performed based on a signal provided by one of the areas defined by the transverse division line **3004**. In these examples, information stored off the track can be reproduced with a sufficiently low level of jitter while reducing the number of signal lines connected to the light detector.

According to the present invention, the following effects, for example, are obtained.

(1) Even when a shift of the objective lens or a radial tilt occur, the difference between $|\text{TEmax-TE0}|$ (difference between the absolute values of TEmax and TE0) and $|\text{TEmin-TE0}|$ (difference between the absolute values of TEmin and TE0) is reduced. TE0 is the value of the tracking

error signal obtained when the center of the track is irradiated by the light, TEmax is the maximum value of the tracking error signal obtained while the light crosses track in the radial direction, and TEmin is the minimum value

5   thereof. Even when the off-track amount is corrected to zero, the degree of asymmetry of the upper and lower amplitudes of the tracking error signal can be restricted to a sufficiently low value. Thus, stable tracking control is performed.

10

(2) Even when the light collection point is off the track, the information stored in the track can be reproduced stably with a sufficiently low error ratio.

15 (3) The fluctuation of the gain of the focusing error signal is restricted to a sufficiently low level. Thus, stable focusing control is performed.

As described above, the present invention provides

20 an optical head device realizing correct information reproduction and stable information recording and erasing with a sufficiently low error ratio. Such an optical head device has higher compatibility with different types of optical information processing apparatuses and different

25 types information memory mediums.

An inclination detection apparatus according to the present invention correctly detects an inclination of the angle made by the beam collected by the collection optical

30 system and the information memory medium even when the inclination is 1 degree or less.

An   optical   information   processing   apparatus

according to the present invention realizes stable information recording to and reproduction from an information memory medium which is significantly curved.

5   Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth

10   herein, but rather that the claims be broadly construed.